JOHN LOUDON MACADAM

The Road-Maker

Sept. 21, 1756—Nov. 26, 1836

THE ART OF ROADMAKING

TREATING OF THE VARIOUS PROBLEMS AND OPERATIONS IN THE CONSTRUCTION AND MAINTENANCE OF

ROADS, STREETS, AND PAVEMENTS

WRITTEN IN NON-TECHNICAL LANGUAGE, SUITABLE FOR THE GENERAL READER; WITH AN EXTENSIVE BIBLIOGRAPHY AND A DESCRIPTIVE LIST OF RELIABLE CURRENT BOOKS AND PAMPHLETS ON THESE SUBJECTS

BY

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TO

EVELYN LYNAS FROST

WHOSE ENCOURAGEMENT LED TO THE PREPARATION OF THIS MATERIAL, AND TO WHOM I AM GREATLY INDEBTED FOR ASSISTANCE IN ITS COMPILATION THIS BOOK IS AFFECTIONATELY DEDICATED

PREFACE

Roadmaking is an art, based on a science. Although it forms one of the most common and most important engineering works that engage the attention of man, the use of roads is so much a part of our daily life that we almost cease to consider their construction and upkeep as problems in engineering. Yet Roads may be said to be the backbone of the national life of a country and the most important element in the progress of civilization from the very earliest times.

This book is intended to give an outline of the history of road building; of the problems that confront the engineer in the location, construction and maintenance of roads; of the properties of the various road-making materials, and of many other features of the subject, and an effort has been made to present this information in a style suitable for the intelligent reader with or without previous technical experience.

No claim is made for originality in the contents, or for the presentation of new ideas or methods; in fact, since the days of Telford and Macadam little advance was made in the science of roadmaking, until the comparatively recent inventions of the modern mechanical methods of quarrying, stone crushing, grading, etc., and the various improved methods of dust prevention, street cleaning, and road maintenance. In the compilation of the material the columns of "Engineering News" and other technical periodicals have been drawn upon, government reports and a few trade publications devoted to the making of roads have been freely quoted, and a large number of treatises have been referred to. Foremost among these may be mentioned Byrne's "Highway Construction," Baker's "Roads and Pavements," Tillson's "Pavements and Paving Materials," Aitkin's "Road Making and Maintenance," Judson's "City Roads and Pavements," and "Road Preservation and Dust Preven-

tion," Soper's "Modern Methods of Street Cleaning," Spalding's "Roads and Pavements," and Coane's "Australasian Roads."

The majority of these publications so specialize in one or more features of the subject, or cover the entire subject in such encyclopedic detail, that they do not appeal to the average non-technical general reader. On the other hand, in spite of the modern specialization of the engineering profession, even the most specialized engineer is often called on to make use of information regarding some form of road work, and although he may be a specialist, and well informed on the subject of drainage, or of automobiles, he may be decidedly ignorant of the methods of roadbuilding and maintenance, which are outside of, but closely allied to, his specialty.

The present book has been written for both of these men. The object has been to condense into the comparatively small space of a single volume, the fundamental and essential principles of the roadmaker's art as presented by the most reliable authorities. It gives to the reader unacquainted with the subject a good general knowledge, and to the technical man, an outline of the main facts and an indication where further reliable and specialized information can be obtained.

To do this, all involved mathematical tables and formulas, records of tests and analyses, tables of statistics and the higher technical features of the subject have been omitted; information that covers pages in some treatises has been reduced to conclusions and tabulated, and such illustrations have been selected that will emphasize the popular features of the subject.

H. F.

220 Broadway, New York,
March, 1910

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THE ROAD *

Soon as I knew you gathered from all lands,
And that my cause was in your skilful hands,
My pulses gave one throb and, with a bound,
To be with you I quitted all my ground,
City and village, forest, hill and plain,
And, Phryne at the judgment once again,
My veil of dust hiding the fears you gave me,
Behold me at your feet, my masters! Save, oh save me!
Oh save me, when I wander o'er the plains
Or, 'twixt the hedges of the country lanes,
I stretch my arms beneath some leafy glade,
Heavy with sleep and flecked with sun and shade;
When like a serpent undulate I glide,
Trailing my white robe up the mountain's side;
When, drunk with light, for breezes fresh I look
And wind along some chattering brook;
When I plunge into chasms, sound the deeps,
Climb to the plateaux, mount the dizzy steeps;
Or when above the mountains, near the skies,
I spread new worlds before men's dazzled eyes
For all the gifts on you I have bestowed,
Be my good doctor—save, oh save the Road!

My case is grave and needs swift remedy;
Never has greater peril threatened me—
True, as in France, so in all other climes,
Much have I suffered from most ancient times.
In days when, sometimes subject, sometimes free,
People met people in fierce enmity,
I bore the shock of many a battle train
Rushing to doubtful death or doubtful gain;
And, like some avalanche of myriad tons,
The murd'rous passage of the heavy guns.

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* Translation of an anonymous poem recited by Mme. Bartet at the Gala Performance given at the Comédie Francaise on Oct. 14, 1908, in honor of the First International Road Congress, Paris. Reprinted from "The First International Road Congress, Paris, 1908." By G. M. Harris and H. T. Wakelam.

Chanting the Marseillaise, thirsting for war
A nation shod with sabots passed me o'er,
And the great Emperor, to spread his fame
Over a world which trembled at his name,
Compelled me to his will and, spurring fast,
Triumphant o'er my prostrate body passed.
Glory I've borne—a heavy load to bear!
And others too as heavy and less fair;
The clumsy cart, rumbling with jolt and jar
Has crushed my bosom, leaving many a scar;
Coach, post-chaise, and postilions in full cry,
Flayed my back sorely, as they galloped by.

The lumber wagon laid my sinews bare!
Yet I stood firm, defying wear and tear,
Even I thought to breathe with greater ease;
My toil, less burdensome, began to please.
No longer coach or post-chaise o'er me whirled,
I was forgot, abandoned by the world.
Rarely some cart with tranquil pace would creep
Me by, the lazy driver half asleep—
Nought else by day or night disturbed my rest,
Thus, by sweet *dolce far niente* blessed,
Thinking my woes forever passed away,
In a false calm I lived until one day—

A terrible monster burst into sight,
God knows from out of what hell 'twas cast.
Sheathed all in iron, a thing of might,
Swiftly it passes—it has passed!

It has passed, with a fearsome hooting,
Trail of smoke and a sudden glare,
Like to some dazzling meteor shooting
Over the highways of the air.

Fast and furious, onward dashing
Tow'rds an horizon which e'er shrinks back;
Fiery bolts of lightning flashing
Over an echoing thunder track!

And ah! for me it means a wound indeed,
My face is crushed, my sides their binding bleed,
Car after car make ever fresh attacks,
Till my macadam's nought but ruts and cracks.

My body thus commences to decay
And, into dust dissolving, floats away!
Must I then die?
No, no! For you are here;
With you to aid me I have nought to fear.
Science and genius are in you allied!
In your great wisdom I can well confide.
Quitting the beaten paths, you'll seek new ways
Towards the cure for which your suppliant prays,
Thresh out fresh doctrines, find the golden mean
And, to preserve the *route* avoid routine!

Your patient's at your feet, apply your skill,
Probe, sound, investigate me as you will,
And, to prevent the tortures of the past,
Perfect a work, my masters, that will last!
Do this, and grateful evermore will be
All travelers—nay, all humanity;
For 'tis the road that is the fertile way,
Where Life and Progress must forever stray;
Where, seeking space and beauty far and wide,
The tourist flings unnumbered miles aside,
And over hills and valleys sows the seed
Which shall bring forth abundance in our need!
And when at length you have achieved your aim,
Restored my health and strengthened all my frame;
When by your work you've made me proof to shock,
Fearless, invulnerable, firm as rock;
My youth renewed, and more than ever fair,
I'll sing your praise here, there and everywhere;
Beneath all skies, telling the joyful story,
At every cross-roads I'll proclaim your glory
On Touring Club sign-posts for all to see!

The surest road to Immortality!

ADDENDA.

Page 23. It should be added to the last paragraph that some of the States have created and financed Highway Commissions, as is detailed on Page 252.

It should also be added that New York State has classified its roads as follows:

2,800 miles of main roads across the State from N. to S. and E. to W., known as "State" Roads, to be built and maintained at cost of State and by the State.

7,500 miles of main "County" roads, being the most important roads in the 47 Counties to be improved by the State, which pays 50%, the County paying 35% and the Town 15%.

70,000 miles of "Town" roads to be improved as *earth* roads under State supervision, at the expense of the Towns, plus an equal sum to be donated by the State as "State Aid."

Page 24. In reference to the last paragraph, while the Massachusetts State Highway Commission is *one* of the most important, at the present time the *most* important highway undertaking is probably that of the New York State Highway Commission, which is charged with the expenditure of the proceeds of fifty million dollars' worth of bonds, having taken from the State Engineering Department the charge of Highways in February, 1909.

Until about 1902 the Massachusetts Highway Commission was the most important State organization, the other States (including New York) learning much from the experience and good work in Massachusetts and meantime exceeding them in mileage. The mileage of New York was about 520 miles in 1909, while the Massachusetts Commission reports show their annual new mileage as: 47 miles finished in 1907, 38 miles built in 1908, and about 45 miles in 1909.

THE ART OF ROADMAKING

INTRODUCTION

HISTORICAL SKETCH OF ROAD DEVELOPMENT*

THE word "Road" (Anglo-Saxon *rad*, a riding, and *ridan*, to ride) is commonly used to mean a public highway, but custom has applied it to any kind of a path open to foot or vehicular traffic. In the most ancient times there were no roads. The wants of man were few and were easily satisfied by nature and his knowledge and intercourse were limited to his immediate vicinity. But as the population of the various communities multiplied, and with it the necessities of life, man was led further afield to supply them. He formed rough pathways, which, in time, came to be the recognized routes from one locality to another, by means of which he satisfied his desire for investigation and intercourse with his neighbors, for the products of other localities, and for conquest.

"Countries inhabited by the least civilized people, whose wants can be supplied in the immediate vicinity of their dwellings, are almost destitute of roads; hence it has come to be said that roads are the physical symbol by which to measure the progress of any age or people. 'If the community is stagnant, the condition of the roads will indicate the fact; if they have no roads, they are savages.'" †

* The majority of current books on the subject of roads open with an introductory historical chapter, but the most comprehensive general histories may be found in Byrne's "Treatise on Highway Construction," and Tillson's "Street Pavements and Paving Materials," and the best as applied to British Roads in Aitkin's "Road Making and Maintenance."

† Byrne: "Highway Construction."

Roads are not only the offspring of civilization, but they are also the greatest contributors to it and the greatest factors in its advancement.

Without them the arts that are so beneficial and necessary to the welfare of man could not develop; the interchange of ideas and the advantages that result therefrom could not be maintained; in fact, the civilization of to-day with its large cities and towns, its commerce, newspapers, and its highly developed moral, physical, and intellectual life, could not exist at all.

One of the very first steps in the opening up of a new country is the location and building of roads for the accommodation of travelers, the carriage of commodities, and for the development of the natural resources and manufactures of the country. Smiles, in his "Lives of the Engineers," says: "The road is so necessary an instrument of social well-being, that in every new colony it is one of the first things thought of. . . . The new country, as well as the old, can only be effectually opened up, as the common phrase is, by roads, and until these are made it is virtually closed."

Of the early history of road building as of other works done in the early life of the human race, little is known; while no authentic records exist, it is known that the importance of good roads was recognized in very ancient times. We are told by Herodotus of a stone roadway built by King Cheops about 4000 B.C., over which were conveyed the heavy materials for the construction of the great Egyptian pyramid that bears his name. We are also told of a broad roadway connecting the ancient city of Memphis with the pyramids and lined on both sides with temples, mausoleums, porticos, monuments, etc. Later historians tell us of the pavements of Babylon, of many paved roadways diverging from that city and of a highway connecting Babylon and Memphis and passing through the great commercial cities of Nineveh, Palmyra, Damascus, Tyre, and Antioch. It is to the Carthegenians, however, that credit must be given for the earliest systematic and scientific efforts at road building, for as early as the fifth century B.C. they had developed a system of

communication and military power that enabled them to maintain their integrity against Greece and the Roman Empire for four hundred years. The Romans learned the art of road building from the Carthagenians, and so fully did they appreciate the military advantages of improved highways that they soon became the greatest road builders of history.

The first Roman road of which we have historical evidence was built in 312 B.C. by Appius Claudius, the censor, and was named after him—the Appian Way. Some years later, the Flaminian Way was built, and under Augustus and Julius Cæsar and succeeding emperors, Rome was made the center of a wonderful system of paved roadways stretching out to all parts of its great empire. These reached through Italy, Gaul, and Spain; through Germany, Hungary, Macedonia; to the islands of Sicily, Corsica, Sardinia, England, and to Africa and Asia Minor and the East; in all, a system of 372 roads, which, according to Antoninus, amount to a total length of 52,964 Roman miles.

It is said that for a distance of fifty miles from Rome many of these roads were decorated with temples and other superb edifices; lodging houses for the accommodation of couriers and mansions for soldiers were erected at regular intervals at the public expense. The width of these military roads was from 36 to 40 Roman feet, the middle portion being for the infantry, and the margins for horses and carriages. Many miles of these roads still remain as great monuments to the energy and skill of the Romans, and show the truth of the familiar saying that "All roads led to Rome."

Not far behind the Romans in the art of road building were the ancient Incas of Peru, who built some thousands of miles of good roads in the face of great difficulties. In his "History of Peru," Prescott says of the mountain road from Quito to Cuzco: "It was conducted over sierras covered with snow; galleries were cut through the living rock; rivers were crossed by means of bridges swung suspended in the air; precipices were scaled by stairways hewn out of the native bed, and ravines of hideous depth were filled up with solid

masonry." Most of this roadway was built at an elevation of 12,000 feet above the sea; it was more than 1500 miles long and 20 feet wide; paved with stones 10 feet square and had a running stream and a row of shade trees on each side.

After the decline of the Roman Empire, the roads fell into disuse and during the succeeding dark ages they were used more as aids to plunder and violence than for purposes of legitimate intercourse. Later they became practicable for pack horses and rude vehicles, but no effort was made to restore them until the middle of the eighteenth century when a revival of road building arose simultaneously in England and France. The highways of England at that time were wretched beyond description and an effort was made to improve this condition by the establishment of a system of turnpikes. Many thousands of miles of these roads were built, but they were little or no improvement over the old roads, and no further advance was made until the time of Macadam and Telford, to whom England is indebted for her present admirable system of roads.

In the United States the highways are much inferior to those of European countries, the reason for which Byrne * states may be attributed to (1) the excellence of the railroad systems and waterways; (2) the indifference of those in charge of highway maintenance; (3) the want of appreciation of the benefits of good roads and the fear of increased taxation on the part of the rural population; (4) the dispersion of the people over large areas in their search for desirable localities for residences, and (5) the ill-effects of the system requiring the personal services of the rural population on the highways.

The first inhabitants of this country were too fully occupied in subduing the wilderness, establishing homes, opening farms to provide the necessaries of life, and setting up the framework of a government, to give much attention to the conveniences and comforts of transportation; and hence their wagon roads were of the crudest and poorest sort.

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* "Highway Construction."p. xxxviii.

Street in Pompeii.

]To face page 4.

Restoration of Street in Pompeii, based on existing remains.

[To face page 5.

Later, just as an extension of the population to the West necessitated the development of better means of transportation, the introduction of the railroad made less important the wagon roads and engrossed the attention of the population of the new territory. In a large part of the United States the railroad has been the pioneer and has rendered unnecessary long lines of wagon transportation. At present the country is so well supplied with excellently managed railroads that the chief function of the wagon road is to afford easy communication and transportation between neighboring farms, and between the farm and the nearest railroad station. Thus the problem of good roads had become a local question, both with respect to the community the road serves and to the materials and methods most suitable for use in the construction.

These facts relate to roads as distinguished from pavements, or road surfaces. The date of the introduction of pavements is very indefinite. In his "History of Inventions and Discoveries," John Beekmann, professor in the University of Göttingen, devotes a chapter to the paving of streets, and from his historical sketch the following more interesting points are taken:

"While Roman writers of early date often refer to paved highways and especially describe the famous Appian Way, of 312 B.C., there is comparatively little reference to the paving of streets in cities. The streets of Thebes were regularly cleaned under the inspection of Telsarchs, and it is to be assumed that they were paved; and the Talmud says that the streets of Jerusalem were swept every day, which undoubtedly implies a hard and solid pavement. There is no record of the first street pavement in Rome; but Livy mentions that certain streets were ordered to be paved in 169 B.C., and as early as 530 B.C. the Emperor Heliogabulus paved the streets around the palace with foreign marble. The streets of Pompeii and Herculaneum still show their paving blocks of lava, cut into deep ruts by the wheels of passing chariots.

"Passing to later times, we find the streets of Cordova,

in Spain, paved as early as A.D. 850, by order of the Caliph, Abderrahman II. The first record of any street paving in Paris is dated in the year 1184, when the name of the city was changed from 'Lutetia,' the dirty, to 'Paris.' This innovation is said to have arisen from the fact that the King, Philip II, was annoyed by the offensive odors produced by the agitation of the mud in front of his palace by passing vehicles. He resolved to remedy the intolerable nuisance by ordering the streets paved, and succeeded in having this done, in part, at least, notwithstanding the heavy cost, which had deterred his predecessors.

"In 1090 the streets of London were soft earth only; but when the first pavement was introduced is not known. Holborn was paved for the first time, by royal command, in 1417; Henry VIII ordered other streets paved, and the great market square of Smithfield was first paved in 1614. Augsburg, in Germany, seems to have been the first city in that country to introduce footways and street pavement, in 1415, but the extension of the improvement to other towns was slow, and the streets of Berlin were not all paved even in 1679."

In the United States, Boston was the first place to pave its streets—pebbles, cobblestones, and flagging being used during the seventeenth century. In New York city the first stone pavement was laid about 1657 on what is known to-day as Stone Street, and the first sidewalks were laid in 1790, on the west side of Broadway.

Toll roads were first constructed in England in 1346, and were built until 1878, when they were entirely abolished. In 1792 a toll road company was incorporated in Pennsylvania to construct and maintain an artificial road from Philadelphia to Lancaster. In 1834, the Albany and Schenectady turnpike was laid with stone wheel-tracks for a distance of fourteen or sixteen miles. The turnpike itself was made in 1805, of gravel, at a cost of $8400 per mile. Ten years later a "sunken pavement" of cobblestones was built on the dry and sandy parts of the road, and broken quarrystone, to the depth of twelve inches, was bedded in the wet and clayey

parts, the edges bonded by lines of small boulders imbedded in the earth along each side.

In 1831 protests were made by the stockholders of this turnpike company against the effect of the charter granted to the Mohawk & Hudson Railroad Company, on the ground that

"Should the railroad company succeed, their operations will necessarily diminish materially the tolls of the turnpike company, and thus sap the consideration upon the faith of which the latter have constructed their road."

Referring to the application of the railroad company for leave to run a side-track into the heart of Albany, Chancellor Kent wrote:

"If that would not be an interference with the rights of the turnpike company, then nothing would be an interference short of plowing up the turnpike road."

It was feared that the railroad might eventually displace the stages, the tolls from which formed a large portion of the revenues of the previously chartered turnpike company, but the steam railroad was built, and was opened to operation on September 12, 1831, as the first exclusively passenger railroad in the world. The handling of freight by the railroad was not begun until December 6, 1832, when three cords of wood, making two carloads, were taken to Albany, and were the first freight carried on what is now the New York Central Railroad. In order to compete with the railroad, the turnpike company then made many efforts to arrange to build another railroad of their own along the side of the turnpike, and the failure of these efforts resulted in deciding, in 1832, to lay the "stone rails," of which twenty thousand linear feet were laid in 1833 and 1834, at a cost, including the cobble paving between the tracks and the forming of the roadbed, of $3300 per mile. Sections of this stone wheel-track, in some cases half a mile or more in length, are still in good condition and in daily use, as shown in the photograph on next page, made in 1901.

About 1862, a system of similar wheel-track roads was built in Ulster County, N. Y., as a toll-road from Kingston,

4 ft. of large cobble pavement. 4 ft. of trackway.

18 in. to 24 in. wide,
4 in. to 6 in. thick.

ROAD FROM ALBANY WEST TO SCHENECTADY, N. Y., 1901.
Built by Turnpike Company in 1834.

Groove worn
6 in. wide, 2 in. deep.

2 ft. wide,
6 in. thick.

ROAD WEST FROM KINGSTON, ULSTER CO., N. Y., 1908.
Built by Turnpike Company in 1862.

STONE WHEEL-TRACKS.

(From Judson's "City Roads and Pavements.")

eight miles up the Delaware and Ulster Valley, to the bluestone quarries in the Catskill mountains. This proved to be so successful that branches, and other roads of the same sort, were soon built and are still in decreasing use.*

The ease of traction on these smooth slabs led to an increase of the loads drawn upon them, until eight tons has been and is an ordinary load for two horses to bring from the quarries to the wharves at Kingston and Rondout, while loads of twelve to fourteen tons are drawn by three horses, and loads of seventeen tons actual weight have sometimes been drawn by four horses. These great loads were formerly carried upon narrow tires of one and one-half to two inches, which speedily cut furrows in the hard stones, so that slabs six to eight inches thick were cut through in three or four years.

* Judson's "City Roads and Pavements."

PART I

PRELIMINARY CONSIDERATIONS

CHAPTER I

RESISTANCE TO TRACTION

BEFORE taking up the study of the location and construction of roads, it is necessary for the reader to understand something of the problems connected with the theory of road-making—the obstructions and resistances to motion to be overcome by the traffic using the road, the financial considerations involved in the construction to insure its greatest economy, and the questions that confront the engineer in making roads to suit the many different uses to which they are put. These problems are outlined in this and the two following chapters.

Object of a road

THE object of a road is to provide means of transportation of persons and goods with the least possible expenditure of time and money. This economy depends upon the amount of resistance to easy motion offered by the road, the causes and effects of which are matters of great importance in determining the ruling gradient to be adopted on a proposed road, according to its situation and the class of traffic that will use it.

Causes of tractive resistance

Resistance to traction is made up of:

1. Axle friction, which is nearly constant at all velocities, and is independent of the condition of the surface of the road.

2. Rolling resistance, due to collisions with irregularities of the surface, and to the penetration or sinking of the tire in the roadway.
3. Gravity, or resistance due to gradient.
4. Air resistance, varying according to the velocity of the wind, the area of the surface acted upon, the velocity of the vehicle, and the angle or direction at which it impinges against the plane of the surface.

The tractive force, or the power required to move vehicles along a road, is variable, depending upon the conditions of the road and the power of the horse. The power of the horse varies in turn, according to its strength, weight and special training, the speed at which it travels and the hours of work, but it may be taken as an average of $\frac{1}{30}$ of the load on a level macadamized road in good repair, varying from $\frac{1}{48}$ of the load on the best roads to $\frac{1}{25}$ on roads with a badly maintained surface.

Power required to move vehicles.

Reliable tests have been made to determine the force required to overcome the combined resistances of the vehicle and the road, resulting in the accompanying table:

TABLE I

STANDARD TRACTIVE RESISTANCE OF DIFFERENT ROADS AND PAVEMENTS *

Kind of Road Surface.	Tractive Resistance.	
	Lbs. per Ton.	In Terms of Load.
Asphalt, artificial sheet	30 to 70	1/67 to 1/30
Brick	15 to 40	1/133 to 1/50
Cobble stones	50 to 100	1/40 to 1/20
Earth roads, ordinary condition	50 to 200	1/40 to 1/10
Gravel roads	50 to 100	1/40 to 1/20
Macadam	20 to 100	1/100 to 1/20
Plank road	30 to 50	1/67 to 1/40
Sand, ordinary condition	100 to 200	1/20 to 1/10
Stone block	30 to 80	1/67 to 1/25
Steel wheelway	15 to 40	1/133 to 1/50
Wood block: Rectangular	30 to 50	1/67 to 1/40
Wood block: Cylindrical	40 to 80	1/50 to 1/25

* Baker: "Roads and Pavements," p. 31.

Recent experiments in tractive resistance.

The resistance of pavements to tractive effort has recently been investigated in the city of Toronto, Ont., and reported to the Canadian Society of Civil Engineers in a paper by Mr. A. C. D. Blanchard. All experiments were made with a good, steady team of horses, weighing 2940 pounds, and drawing a truck weighing 2710 pounds, with a load of 8570 pounds. Between the horses and the truck there was placed a standard dynamometer which was read by an observer on the truck, at stated distances paced and called out by the notekeeper walking alongside. Observations were made on wet and dry streets of varying grade and paved with asphalt, bitulithic, brick, cedar block, granite block, and treated wood block. From the figures so determined curves have been plotted on grade of street as an abscissa and tractive resistance as an ordinate. For dry streets these curves, which are straight lines, show the brick paving to have the least resistance, the others following in the order: treated block, bitulithic, cedar block, granite block, asphalt. These lines all show a fairly uniform rate of increase of resistance with grade, except that the granite block seems to increase its resistance with grade somewhat more sharply than the others.

On wet streets, the order of tractive resistances, beginning with the lowest and going up is: bitulithic, asphalt, treated block and cedar block. Wet brick pavements were not tested. The wetness of the streets seems to show small effect on the resistive powers of the pavement. The high place of the asphalt in the list of dry weather records is due to, no doubt, the fact that dry weather is hot weather and the asphalt pavement then is rather a soft mass into which the wheels of a wagon sink. On wet, and therefore cold and hard, asphalt pavements, the asphalt shows a very low resistance.

Calculation of tractive force.

The tractive force required to overcome obstacles is equal to the horizontal force required to raise the wheel the height of the obstruction when applied directly to the axle, and may be calculated as follows:

In Fig. 1, let P = power required to overcome obstacle B, acting in direction AP, with the leverage x.
W = Weight, or Gravity, resisting in direction WA, with leverage y.

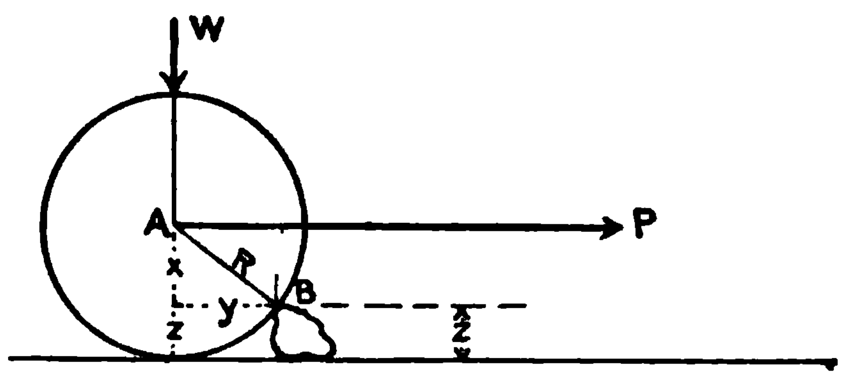

Fig. 1.

This makes an equation of equilibrium

$$Px = Wy, \quad \text{or} \quad P = W \times y/x$$

or in terms or radius R, where z = height of obstruction

$$P = W\sqrt{R^2 - x^2}/(R - z).$$

Example. Let radius of wheel be 26 inches; height of obstruction be 4 inches; and the weight of wheel and load on axle be 500 pounds.

Then $P = 500\sqrt{676 - 484}/(26 - 4)$;
$= 500 \times \sqrt{192}/22$;
$= 500 \times 13.86/22 = 314.9$ pounds.

The pressure at point $B = W \times R/x = 500 \times 26/22 = 591$ pounds.

Rolling friction

Rolling friction is affected largely by the width of the tires and can be materially decreased by increasing their width, a tire of 2½ inches wide causing fully double the wear of one 4½ inches wide. The only exceptions to this are in cases of

1. Hard and incompressible surfaces, where width makes little difference in traction, the advantage being in favor of the narrow tire.
2. Sticky and dusty surfaces, where the large quantity of mud and dust raised by the wide tires increases the draft.

A solid rubber tire offers slightly less resistance than an

iron one if the road is wet and heavy, but more if the surface is hard and smooth. Pneumatic tires reduce tractive resistance from 25 to 50 per cent, in increasing proportion as the road grows worse.

Effect of size of wheels

The size of the wheel also has much to do with tractive resistance. Acting on the principle of a lever, small wheels increase, and large wheels decrease, resistance, provided the diameter of the wheels is not so great that the line of traction will be downward and consume part of the power of the horse by pressing the wheel against the ground. The most economical size of wheels is considered to be about six feet in diameter.

Effect of springs

The effect of springs on vehicles is to diminish the wear on roads, especially at speeds beyond a walking pace. Going at a trot, they cause no more wear than vehicles without springs at a walk, all other conditions being equal.

General results of experiments in tractive resistance

The following are the general results of experiments made by M. Morin upon the resistance to traction of vehicles on common roads: *

1. The resistance to traction is directly proportional to the load, and inversely proportional to the diameter of the wheel.

2. Upon a paved or a hard macadamized road the resistance is independent of the width of the tire, when this exceeds from 3 to 4 inches.

3. At a walking pace, the resistance to traction is the same, under the same circumstances, for carriages with springs and for carriages without springs.

4. Upon hard macadamized roads and upon paved roads, the resistance to traction increases with velocity—the incre-

* Of the many experiments made by the English, German, and French engineers on the force necessary to pull different vehicles at various speeds over various surfaces, those made by M. Morin in 1838–41, seem to have been the most extensive series, and were made with much care and a high degree of accuracy. They were first described by him in his "Experience sur le tirage des Voitures," Paris, 1842, and have been referred to by nearly all modern writers.

ments of traction being directly proportional to the increments of velocity above the velocity of 3.28 feet per second, or about 2¼ miles per hour. The equal increments of traction thus due to equal increments of velocity are less as the road is smoother, and as the carriage is less rigid or better hung.

5. Upon soft roads of earth, sand, turf, or roads fresh and thickly graveled, the resistance to traction is independent of the velocity.

6. Upon a well-made and compact pavement of hewn stones, the resistance to traction at a walking pace is not more than three-fourths of the resistance upon the best macadamized roads, under similar conditions. At a trotting pace the resistance is equal.

7. The destruction of the road is, in all cases, greater as the diameters of the wheels are less, and it is greater in carriages without than in those with springs.

Gradient

The grade of the road is the quantity by which it differs from the level. Theoretically, all roads should be level, and where they are not so, a large portion of the tractive force of the vehicles traveling over them will necessarily be expended in raising the load up the ascent. This resistance of the force of gravity, or weight to be overcome, is the same on all roads in any condition, and is in all cases approximately equal to the load divided by the rate of grade. That is, the grade resistance on any incline in pounds per ton is 2240/Rate of Grade, from which the following table has been computed:

TABLE II

RESISTANCE DUE TO GRAVITY ON DIFFERENT INCLINATIONS

Grade, 1 in	20	30	40	50	60	70	80	90	100	200	300	400
Rise in feet per mile.	264	176	132	105	88	75	66	58	52	26	17	13
Resistance in pounds per ton	112	74½	56	45	38	32	28	25	22	11¼	7½	5½

On account of this loss of power on inclinations, it is important not to allow a road to ascend or descend a single foot more than is absolutely unavoidable. In case of ascending a hill, the road should be so located and have such cuttings

and fillings as will secure a gradual and uninterrupted ascent the whole way, as the slightest fall would make an additional, and probably a steeper, incline.

Loss of power on inclinations

The necessity of easy gradients is dependent upon the power of the horse to overcome the total of the four elements of resistance to motion. On a level, smooth road, the pull which a good average horse, weighing 1000 to 1200 pounds, can exert at a walking pace, is about 100 pounds, or one-tenth his weight.

Necessity of easy gradients

A 1650-pound horse can develop the conventional horse-power of 550 foot-pounds per second and 16,500,000 foot-pounds per day of eight and one-third hours, which, however, may be considered as the limit of endurance. If the time of effort is decreased, the draft may be proportionately increased, and vice versa. The maximum draft for a horse is about half his weight, and under certain conditions, this may be two-thirds, but the working tractive power may be safely taken as one-tenth, with an average maximum of one-quarter the weight, which may, in great emergencies, be increased to one-half.

Hauling power of horses

Increasing the number of horses does not increase the power proportionately. With teams, the tractive power is about as follows:

Power of teams.

1 horse	1
2 horses	$0.95 \times 2 = 1.90$
3 horses	$0.85 \times 3 = 2.55$
4 horses	$0.80 \times 4 = 3.20$

The gross load that can be drawn by a horse on any grade

Calculation of load on a gradient.

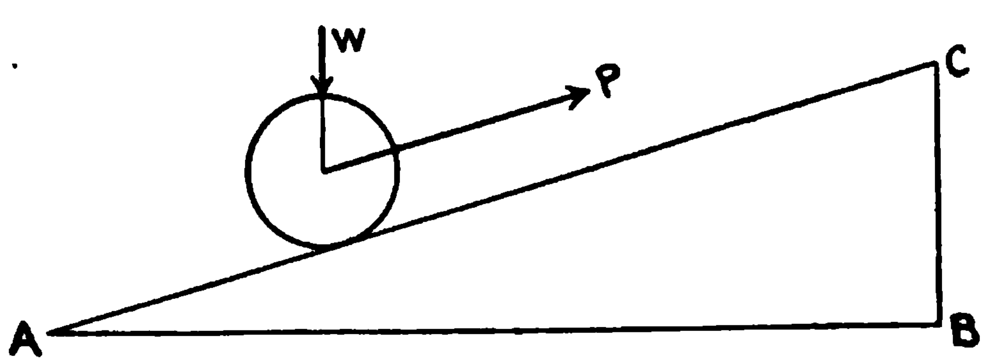

Fig. 2.

can be approximately calculated by the formula:

$$L = (t - W/R) \div (T + 2240/R);$$

where L = load in tons, inclusive of vehicle,
t = tractive pull of horse in pounds,
W = weight of horse in pounds,
T = tractive force required to haul one ton on a level (See Table I),
R = rate of grade, or horizontal distances in which the rise is unity; $BC:AB$. (See Table II).

Example. What load can a good horse, weighing 1500 pounds, haul on an ordinary country earth road ($T=150$) on a gradient of 1 in 20, when exerting a pull of 200 pounds?

$$L = (200 - 1500/20) \div (150 + 2240/20);$$
$$= (200 - 75) \div (150 + 112);$$
$$= 125/262 = .477, \text{ or about } \tfrac{1}{2} \text{ ton.}$$

Actual experience has shown that a good average horse can draw on a level earth road in best condition a load of about 3600 pounds, which is reduced on grades as follows:

	Pounds.		Pounds
1 per cent grade.......	2880	5 per cent grade......	1476
2 " " "	2376	10 " " "	936
3 " " "	1980	15 " " "	360
4 " " "	1692	20 " " "	144

Load drawn by horses on grades.

In ascending inclines a horse's power diminishes rapidly. A large portion of his strength is expended in overcoming the resistance of gravity due to his own weight as well as that of the load; also by fatigue on a long ascent owing to his anatomical formation and great weight, while the amount of foot-hold afforded by the road surface seriously affects the size of the load he can draw.

Assuming a wagon weighing 1200 pounds, with a load of 1800 pounds, amounting to 3000 pounds, the force of gravity on a

1 per cent grade would be approximately 30 pounds,
2 " " " " " " 60 "
5 " " " " " " 150 "
10 " " " " " " 300 "

and so on, being always constant, regardless of the condition of the road.

Steep grades objectionable.

Steep grades are thus seen to be objectionable, and they are particularly so when a single one occurs

in an otherwise comparatively level road, in which case the load carried over the less inclined portions must be reduced to what can be hauled up the steeper portion.

Their bad effects are especially felt in winter, when ice covers the road, for the slippery condition of the surface causes danger in descending, as well as increased labor on ascending. Rain water runs down the road and gullies it out, destroying its surface and causing a constant expense for repairs, while the inclined portions are subject to greater wear from the feet of horses ascending and require thicker covering than the more level portions, thus increasing the cost of construction.

The correct determination of grade is of the utmost importance in road building. It is expressed in different ways, generally by percentage. A 1 per cent grade means a rise of 1 foot for each 100 feet of horizontal distance traveled. There are 5280 feet in a mile; hence, a 1 per cent grade means a rise of 52.8 feet in that distance, a 2 per cent grade a rise of 105.6 feet, and a 10 per cent grade a rise of 528 feet.

Methods of expressing grade.

The proper grade in each case must be determined by the conditions and requirements. This selection of grade is further discussed, in its relation to the location of roads, on p. 45.

TABLE II*a*

VARIOUS METHODS OF INDICATING GRADE

American Method. Feet per 100 Feet.	English Method.	Feet per Mile.	Angle with the Horizon.	American Method. Feet per 100 Feet.	English Method.	Feet per Mile.	Angle with the Horizon.
¼	1:400	13.2	0° 8′ 36″	3½	1: 28½	184.8	2° 0′ 16″
½	1:200	26.4	0 17 11	3¾	1: 26⅔	198	2 8 51
¾	1:150	39.6	0 22 55	4	1: 25	211.2	1 17 26
1	1:100	52.8	0 34 23	4¼	1: 23½	224.4	2 26 10
1¼	1: 80	66	0 42 58	4½	1: 22¼	237.6	2 34 36
1½	1: 66⅔	79.2	0 51 28	4¾	1: 21	250.8	2 43 35
1¾	1: 57¼	92.4	1 0 51	5	1: 20	264	2 51 44
2	1: 50	105.6	1 8 6	6	1: 13⅔	316.8	3 26 12
2¼	1: 44¼	118.8	1 17 39	7	1: 14 2/7	369.6	4 0 15
2½	1: 40	132	1 25 57	8	1: 12½	422.4	4 34 26
2¾	1: 36⅛	145.2	1 34 22	9	1: 11⅑	475.2	5 8 31
3	1: 33⅓	158.4	1 43 08	10	1: 10	528	5 42 37
3¼	1: 30¾	171.6	1 51 42				

CHAPTER II

ROAD AND PAVEMENT ECONOMICS

Value of good roads

Good country roads and city streets possess a considerable value, as on them depend largely the development of the financial, social and educational well-being of the community. In cities and towns, smooth and comparatively dustless roads are regarded as essential to the comfort and health of the inhabitants. In the rural districts, the conditions of life being so different and ways and means entering so largely into consideration, the same arguments do not apply, but the monetary advantages of good roads are none the less apparent.

No enumeration of the advantages of good country roads could include all the benefits, but a few of the most evident of these may be mentioned, as follows:

1. Decrease in cost of haulage.
2. Better facilities in the marketing of crops, thus permitting the cultivation of crops not otherwise marketable—an especially valuable feature to farmers located in the vicinity of a large city.
3. The marketing of produce at the most favorable times—an important consideration in connection with perishable products.
4. A wider choice of market.
5. The equalizing of railway traffic and mercantile business between different seasons of the year.
6. The promotion of social and intellectual intercourse between members of rural communities and also between rural and urban populations.
7. Consolidation of rural schools and the increase in their economy and efficiency.
8. Facilitation of the rural mail delivery.

9. Increase in value of rural property by making it more accessible to cities.

Highway improvements in rural districts should be considered for both their financial and intellectual benefits, and are to be urged principally because they increase the intelligence and value of the citizen to society. The effects of pavements on city life are also far-reaching and important, but should be studied more particularly in connection with their cost, healthfulness and appearance. Among their principal advantages may be mentioned the following:

Advantages of paved city streets

1. Decrease in cost of transportation.
2. Increase in fire protection.
3. Establishment of a permanent grade—an important feature in connection with all street improvements.
4. Improvement in general appearance of streets.
5. Improvements in standards of sanitation and health, by decreasing dust and mud and facilitating the cleaning of streets.
6. Facilitation of social intercourse and pleasure driving.

These and the many other advantages of a well-paved street, naturally enhance the value of abutting property, so that this must also be included in any list of the benefits derived.

Economic value of road improvements.

The chief financial advantage of good roads and pavements is the lowering of the cost of transportation, by permitting faster traveling and the hauling of heavier loads, and by reducing the wear and tear on horses and vehicles. Just what the economic value of road improvements may be depends on location, cost of improvements, maintenance charges, class of traffic, and other considerations, and is always a difficult problem to solve. A distinction must be made between traffic carried on regularly by an organized transportation department, such as an express company, and occasional traffic carried on by farmers; also between the transportation of perishable and non-perishable products, the marketing of the former being compulsory under any conditions, while the latter can wait for comparatively favorable conditions.

The cost of transportation to the average farmer producing non-perishable products depends chiefly upon the condition of the road surface, and upon the demands of general farm work. Loam or clay roads, which form the most common variety in this country are reasonably good when dry, while sand roads are at their worst when dry and are therefore in their worst condition during the greater part of the year, and especially so during the crop season. In a busy season, the cost of haulage on a fairly level loam or clay road is probably not over 10 or 12 cents per ton-mile, and where farm work is not so pressing, this may be reduced to 8 or 10 cents per ton-mile.*

There is no method of ascertaining definitely the value of improvements or the saving in cost of transportation or the loss occasioned by bad roads; the only way of arriving at such conclusions being either by (1) mere guess work; (2) a rough estimate based upon the estimated annual saving per horse, multiplied by the number of horses given in the census report; (3) statistical results published by the United States Department of Agriculture; (4) making an estimate of present cost per ton-mile and an estimate of cost after the improvement.

While the actual value can with difficulty be established, it cannot be denied that such improvements are beneficial, but before deciding upon their design, the question of ultimate economy should be fully gone into. This includes:

Ultimate economy of road improvements.

1. Interest on first cost.
2. Annual payments to a sinking fund for the extinction of the debt at the end of some time corresponding to the life of the structure, or with a fixed period within which payment must be made.
3. Maintenance and cleaning charges.
4. Equal annual payments to a depreciation or renewal fund which, properly invested for a number of years corresponding with the life of the structure, will provide at the end of the term the amount required for rebuilding.

* The subject of "Cost of Wagon Transportation" was discussed very fully by Prof. I. O. Baker, in the Proc. of Ill. Soc. of Engineers, vol. 16; abstracted in *Engineering News*, of Jan. 31, 1901.

In the designing of city pavements the questions of comfort and luxury as affected by freedom from dust, noise, and slipperiness, enter very largely. Granite, for instance, makes a durable and, in the long run, an economical pavement, but its use in cities is limited, if not precluded altogether, on the grounds that it is noisy, slippery, and destructive to horses' feet.

Questions affecting design of city pavements

It will be seen, therefore, when attempting to adjust the economical value of pavements, how local conditions and necessities must be given full weight. It may be said, however, that well-paved sidewalks and roadways form an economic and social necessity to any community that wishes to preserve its existence. Without them it cannot compete with other places thus properly equipped. The lack of pavements or the presence of bad pavements impedes the moving of people and materials, prevents proper street cleaning, endangers the comfort and health, and retards the character, education, and success of the people.

The question of cost of city pavements is a relative one, but in the matter of payment for them, there is always some discussion. The three most common methods of apportionment of cost are:

Methods of payment for city pavements.

1. Muncipality to pay entire cost.
2. Municipality and abutting property to pay 50 per cent each.
3. Abutting property to pay entire cost.

There are arguments both for and against each of these systems. It is claimed that (1) the residents who do not own a horse or vehicle or make actual use of the pavement should not be required to pay for it, ignoring the other advantages conferred upon them by the pavement; (2) as the pavement is for the benefit of the general public, the cost should be divided, which overlooks the distinct benefits secured by abutting property, but tends to discourage an extravagent demand for improvements; (3) the benefits accrue only to the abutting property, which should, therefore, bear the entire expense, disregarding the fact that the pavement is for the use of the general public and benefits all the people of the community.

In a paper on "Theory and Practice of Special Assessments,"* J. L. Van Ornum gives a table showing the apportionment of cost of pavements in fifty American cities, which shows, for original paving, in 11 cases the city pays all, in 7 the cost is divided and in 32 the property pays all; for re-paving, in 20 cases city pays all, in 8 cost is divided and in 22 property pays all; for grading, in 16 cases city pays all, in 6 cost is divided and in 28 property pays all. This table also shows that as a rule the Eastern and Southern cities pay a larger proportion of the cost than do the Western, which is probably due to the limited revenues of new cities and to the many demands upon the general tax fund. It seems to be equitable and just that the cost should be borne jointly by the private property and the city at large, since then the cost falls upon both interests which directly profit by the improvement, and neither receives a substantial benefit without sharing in its cost.

Administration of highways

The administration of highways is a feature of road economics that has had much attention. Roads should not be considered merely as local facilities for traffic; it is possible to develop them into great trunk lines with many branches, just as a railroad may have many branches connecting the main line with fertile agricultural districts and great commercial centers. One of the greatest values of the road is in reaching where the railroad cannot. There is no other means of traveling or hauling which possesses the advantages of through communication from farm and garden to market, from house to office, from dairy to factory or shop, or for pleasure travel, that are offered by a complete and consistent system of roads.

The management of roads in this country rests almost entirely upon local township or county authorities, and this makes it difficult to secure either good country roads or an efficient road administration. As a remedy it has been urged that roads be classified according to their importance into State, County, and Township roads, each class

* Trans. Am. Soc. C. E., Vol. 38.

to be under a corresponding administrative board. Similar classifications are made in many European countries, and their systems of administration, which have been in force for many years, have produced the magnificent roads seen in Europe to-day. In France, where the road system has been brought to the highest state of efficiency, there are five great classifications:

European systems of management.

1. *Routes Nationales*, or national highways, government roads, managed by government engineers of the Department of Bridges and Roads (Ponts et Chaussées).

2. *Routes Departmentales*, or department highways, maintained at the joint cost of the government and the communes.

3. *Chemins Vecivaux de Grande Communication*, or main feeder roads.

4. *Chemins Vecivaux d'Intéret Commune*, or district roads.

These two classes are made at the cost of the communal funds, with departmental or government subsidies, and are maintained largely by the Department, partly by the communes, and partly by individual labor.

5. *Chemins Vecivaux Ordinaires*, or small local or parish roads, made by the communes with government subsidies, and maintained by communal tax and a part of the days of "prestation."

In Germany the control of the public roads belongs to the several states, and the standard of maintenance in some is very high. There are usually two divisions: the Staats-Strassen, or state roads, and the Lands-Strassen, or local roads. In Italy and Spain there are three classes of roads: National, Provincial, and Communal. In Austria there are Provincial, Subventioned or Competition, and Community roads, under the authority of provincial committees, district road boards and the communities. In Denmark there are four classes of roads, classed according to the number of vehicles that pass over them.

In the United States the most important highway undertaking is that of the Massachusetts State Highway Commission, appointed in 1893 by an Act of the Legislature for improving, making, and encouraging the making of roads. In several other states there are high-

American systems.

way departments, or commissioners, some of which are empowered to give financial and other help for country and local roads. But neither a general system of road classification nor of state aid for road building and maintenance has as yet been established.

For the maintenance of country roads there are three forms of tax:

1. A tax upon the traveler, by a system of toll roads, conducted on the theory that the travelers over a road are the recipients of its benefits and should pay for it. The disadvantages and the many evils of this system have caused it to be almost entirely abolished both in Europe and in the United States.

2. A capitation tax, or poll-tax, which is levied in nearly all states. This is usually paid in labor and in many parts of the country is nearly the sole support of the roads.

3. A property tax, either by a special assessment on all property within a certain distance of the improvement, or by a general tax on all property within stated districts.

The labor tax.

The labor tax system, as regularly employed in many states, was brought from England, and is a survival of the feudal method of requiring all able-bodied men to render public service. It is still in operation in some of the European countries, but upon a much less extensive scale than in this country. The system has many defects, but these are owing rather to poor administration than to the actual working of the system, and may be classified as follows:

1. Indifferent and inefficient work.

2. Impossibility of getting the work done at the most suitable times.

3. No selection of the laborer.

All of these are important considerations, but they are partly counterbalanced by the facts: (1) that the farmer is willing to pay more in labor than in money; (2) that in rural districts it is impossible to secure anyone to do road work at reasonable wages at the most suitable times, and (3) that if the tax were paid in money there would be no certainty that the labor

would be any more efficient. The labor-tax system is not necessarily the cause of inferior roads nor the cash-tax in itself the cause of improved roads. The one thing necessary for successful road management is effective supervision of the work. Without it neither system will accomplish much, and with it either system will do well.

The methods of payment for the maintenance of city pavements have already been briefly mentioned;* the system of maintenance is usually either by a contractor's guarantee† for a specified time, or by the municipality, depending upon local conditions.

Maintenance of city pavements.

In the course of an address before the Civic Association of Morristown, N. J., in 1908, Col. J. W. Howard spoke of the difficulties experienced by municipalities in the methods of pavement construction and maintenance, and said:

"The best pavements are obtained and maintained by employing experienced, efficient and honest men and by eliminating so-called practical politicians, whether office holders, party managers or others. Paving contractors and the men who supply paving materials not only must include in their charges against a city or taxpayer the cost of construction or materials and labor, but also any amounts they expend for bribery (called "graft" by many), and political contributions, thus either increasing the cost of pavements or making their quality bad. If full printed forms of contracts and complete specifications are prepared by a competent paving expert not under local influences, the community receives the benefit of the experience of many other places, and if the specifications enumerate the preliminary laboratory tests which the paving materials must meet, and fully describe the materials, methods, and processes, then with honest inspection, good and durable pavements will be the result."

A serious cause of the destruction of pavements in the United States and a difficulty in the way of proper maintenance,

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* The subject of the apportionment of expenses and the system employed in building, maintaining, and grading roads and pavements is an important one and is discussed very fully in Baker's "Roads and Pavements" and in Byrne's "Highway Construction."

† The subject of "Guarantees" is discussed briefly in Appendix II.

is the frequency with which they are torn up for the introduction and replacing of underground pipes. As the pavement should be impervious to water, it should also be impervious to the destroying pick and shovel of the ignorant workman, to whom this work is usually assigned. A pavement once torn up in this way is never properly repaired, and will always be a source of expense. In most European countries, neither corporations nor individuals are permitted to disurb the pavements, all removals and restorations being done by the city's own employees, upon the deposit, by the parties who required the opening of the street, of a sufficient sum to cover the expense of each piece of paving done, at a fixed price per yard, according to the kind of pavement. The only way to entirely avoid this disturbance is by the introduction of a series of subways under the pavements for wires, pipes, etc.; a costly, but, in the end, an economical remedy.

Opening of pavements.

CHAPTER III

PRINCIPLES UNDERLYING THE SELECTION OF PAVEMENTS FOR DIFFERENT PURPOSES

Road and pavement—definitions.

A ROAD may be defined as a highway or thoroughfare for the use of foot travelers or vehicles; a PAVEMENT (from the Latin *Pavimentum,* "a floor rammed or beaten down") as the artificial surface or covering of the road. Its purpose is not, as may be commonly supposed, to support the vehicles passing over it, the weight of which, together with that of the covering itself, must be actually borne by the natural soil, but it is (1) to distribute the pressure of the traffic over a sufficient area of sub-soil; (2) to facilitate travel by reducing the resistance to traction to the lowest practicable limit, at the least cost for construction and maintenance, and (3) to secure a water-tight covering that will preserve the natural soil from the effects of moisture.

Requirements of a good pavement.

The pavement, or road covering, is composed of suitable materials laid upon a firm bed, or upon an artificial foundation from which water is excluded by suitable drainage, and should be:

1. Cheap—that is, low as to first cost.
2. Hard and durable, to resist wear and disintegration.
3. Easily cleaned.
4. Adaptable to every grade with little resistance to traction.
5. Non-slippery, affording a good foothold for horses.
6. Cheaply maintained.
7. Suitable for every class of traffic.
8. Impervious to water, yielding neither dust nor mud, and noiseless.

Of these requirements (1), (2) and (6) affect the taxpayers, both as to the serviceable life of the pavement and as to the

amount of annual repairs; (3) and (8) affect the occupiers of adjacent premises, who suffer physically, and the owners of the premises, whose income from rents is diminished by these disadvantages; (4), (5) and (7) affect the traffic and determine the cost of haulage and limitations of loads, speed, wear and tear of horses and vehicles.

Properties of an ideal pavement

Assuming an ideal pavement possessing these different properties in perfection, and giving it a value of 100, Tillson* assigns to each its proportional value of the whole as follows:

Cheapness	14	
Durability	21	
Ease of cleaning	15	
Light resistance to traffic	15	
Non-slipperiness	7	
Ease of maintenance	10	
Favorableness to travel	5	
Sanitariness	13	
	—	100

Baker† divides the properties of the ideal pavement into Economic and Sanitary Qualities and Acceptability, and gives a table showing the following relative values of the different qualities:

Economic Qualities:		
Low first cost	15	
Low cost of maintenance	20	
Ease of traction	10	
Good foothold	5	
Ease of cleaning	10	
	—	60
Sanitary Qualities:		
Noiselessness	15	
Healthfulness	10	
	—	25

* "Street Pavements and Paving Materials," p. 147.
† "Roads and Pavements," p. 583.

Acceptability:

Freedom from dust and mud......	10		
Comfortable to use................	3		
Non-absorbent of heat............	2		
	—	15	100

Cheapness is placed first as the first cost of a material is a question of vital importance in deciding upon its availability. No matter how desirable or how economical a material may be, if the property owners cannot pay for it, the question is settled at once and a committee's recommendation is often rejected when its wisdom is not questioned, simply on this account.

Durability is also an economic question, upon which depends ultimate cost, and it must, therefore, be considered in connection with first cost. A pavement may be cheap, and also fill several other requirements but it cannot be a complete success unless it has durability. This is affected by many and various conditions and is measured by the amount of traffic tonnage it will bear before it becomes so worn that the cost of replacing it is less than the expense incurred by its use.

Ease of Cleaning. The experience of many cities has demonstrated the importance of this quality. Street cleaning is an expensive process and considerable attention is given to devices and systems of construction that will effect economies in this direction.

Resistance to Traction is an important item, as one of the objects in the building of a pavement is to effect its greatest possible reduction.

Non-slipperiness is necessary in a pavement, as on it depends the efficiency of a draft horse or other motive power.

Ease of Maintenance is closely allied to first cost. There is not a pavement, just as there is no other work of man, however perfect originally, that will not require constant attention to keep it in its original condition, and the construction that requires the least attention to keep in good repair, and allows that to be done at the least expense, is the best.

Suitability for Traffic means the ease and comfort obtained

by the user of the road and the wear and tear on the horses and vehicles used.

Sanitariness. To be sanitary a pavement must be impervious to water in order to prevent the accumulation of decaying organic matter, garbage, droppings, and various kinds of filth from collecting in joints or soaking through the surface to the underlying soil, out of reach of the street cleaners. It should be of material that will not decay, or otherwise yield dust or mud. Under this head should also be classed noise, which is an important factor affecting the comfort of the persons living adjacent to or otherwise using the street.

Relative values of qualities of different pavements

Tillson* makes a comparison of the various pavements in connection with these properties, as shown in the accompanying table:

TABLE III

SHOWING HOW EACH MATERIAL STANDS RELATIVELY TO OTHERS AND ALSO WHAT PROPORTION OF THE PROPERTIES OF A PERFECT PAVEMENT IS POSSESSED BY EACH PAVEMENT UNDER CONSIDERATION

Pavement Qualities.	Percentage.	Granite A.	Granite B.	Asphalt.	Brick.	Belgian.	Macadam.	Cobblestone.
Cheapness	14	2	4	4	3	5	7	14
Durability	21	21	17	15	13	17	7	15
Ease of cleaning	15	11	8	15	12	7	5	2
Light resistance to traffic	15	7	6	15	12	6	6	4
Non-slipperiness	7	6	5	3	6	3	7	5
Ease of maintenance	10	10	7	6	6	7	3	2
Favorableness to travel	5	3	2	5	4	2	5	0
Sanitariness	13	9	7	13	11	5	5	2
Total	100	69	56	76	67	52	45	44

Making Asphalt the standard at 100, the values of the others will be: Granite A, 91; Brick, 88; Granite B, 74; Belgian, 68; Macadam, 59; Cobblestone, 58.

* "Street Pavements and Paving Materials," p. 167.

The United States Forestry Service recently made an investigation in order to obtain opinions from engineers of a number of American cities who have had experience with the modern creosoted wood block pavement as to the comparative qualities of different kinds of pavements. This was made in a form slightly modified from the one presented above, by Tillson, and resulted in the percentages given in Table IV, in which the figures given are the averages of ten replies to the inquiry. In this table the pavement ranking first under any given quality is given the full quality percentage, the rest grading down from this value in proper proportion.

TABLE IV

COMPARATIVE VALUE OF DIFFERENT PAVEMENTS*

Pavement Qualities.	Percentage.	Granite.	Sandstone.	Asphalt (Sheet).	Asphalt (Block).	Brick.	Macadam.	Creosoted Wood.
Cheapness (first cost)	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	12.5	6.0	14.0
Ease of maintenance	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low tractive resistance	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Non-slipperiness	7	5.5	7.0	3.5	4.5	5.5	6.5	4.0
Favorableness to travel	4	2.5	3.5	4.0	3.5	3.0	3.0	3.5
Acceptability	4	2.0	2.5	3.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
Total	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0
Average cost per square yard (1905)	...	$3.26	$3.50	$2.36	$2.29	$2.06	$0.99	$3.10

Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc., and chiefly concerns the pedestrian and the adjoining resident.

Cost per square yard includes concrete, but not excavation, curbing, etc.; except for macadam which is not usually laid on concrete.

As in Table III, giving Asphalt (sheet) the value of 100, the values of the others will be, approximately: Granite, 95.0; Sandstone, 98,; Asphalt (block), 104; Brick, 99; Macadam, 72; Creosoted wood, 104.

* From Circular 141, Forest Service, U. S. Department of Agriculture.

By a proper understanding and use of these tables, the principles used in their construction can be easily applied to any particular case. One or two examples will suffice to make this clear. Assume a street over which the traffic must be heavy and continuous; ultimate cost is of so great importance that it overrules first cost. Light resistance to traffic and foothold for horses are ruling elements, so that a given power may move its maximum load. The items first to be studied are, then: durability, maintenance, traction, and non-slipperiness. Consulting Table IV and combining the values for these items, Granite has a value of 43.5; Sandstone, 44.0; Asphalt (sheet), 35; Asphalt (block), 40; Brick, 39; Macadam, 25, and Creosoted wood, 41.5. Granite and sandstone have almost equal advantages and a selection must be made between them, according to local conditions.

Use of tables in selection of pavements.

In a residence district built up with homes, there is quite a different problem. Cost, durability, and maintenance are secondary considerations. Ease of cleanliness, non-slipperiness, favorableness to travel, acceptability, and sanitariness are the governing characteristics, and we find that Granite has a value of 29; Sandstone, 32; Asphalt (sheet), 38; Asphalt (block), 37.5; Brick, 34; Macadam, 22.5, and Creosoted wood, 38. Asphalt or creosoted wood, either of which possesses all the desirable qualities in so high a degree, should be selected without question.

The following table shows the comparative rank of pavements in the order of their merit, as given by Byrne: *

TABLE V

COMPARATIVE RANK OF PAVEMENTS, NAMED IN THE ORDER OF THEIR MERIT

	Durability.	Serviceability.	Hygienic Fitness.	Service on Grades.	Gross Annual Cost.	Facility for Cleansing.
1	Granite	Asphalt	Asphalt	Granite	Asphalt	Asphalt
2	Asphalt	Brick	Brick	Brick	Brick	Brick
3	Brick	Wood	Granite	Wood	Wood	Granite
4	Wood	Granite	Wood	Asphalt	Granite	Wood

* "Highway Construction," p. 21.

In general, the selection of a suitable pavement to meet any local conditions of traffic is a problem involving questions of adaptability, desirability, serviceability, durability, and cost; but, apart from strictly local considerations, appearance, cleanliness, healthfulness, and noise should be considered.

Adaptability.

In regard to adaptability, the materials most commonly employed are:

1. For country roads—earth, sand, clay, gravel, and broken stone.
2. For suburban streets, parks and pleasure drives, and main country roads—broken stone (macadam), tar-macadam, gravel, vitrified brick.
3. For city streets having heavy and constant traffic—rectangular blocks of stone laid upon a concrete foundation with the joints filled with bituminous or Portland cement grout.
4. For city streets devoted to lighter traffic, and where comparative noiselessness is essential—sheet asphalt, asphalt block, vitrified brick, creosoted wood block, concrete.

Desirability.

The desirability of any pavement depends partly upon its fitness for service, but is dependent principally on the personal prejudices of the persons using or seeing it. Between two or more pavements alike in cost and durability, there will always be a diversity of opinion as to desirability according as each possesses qualities that make it satisfactory for the individual purposes of each person. The economic desirability is governed by the ease of movement over a pavement, and is measured by the tractive power required to move a given weight over it.

Serviceability

The serviceability of a pavement is its quality of fitness for use, as measured by the expense caused to the traffic using it, such as the wear and tear on horses, vehicles, loss of time, etc. This is estimated to be as follows:

	Cents per Mile Traveled.
On Cobblestones	5
Belgian block	4
Granite block	3
Wood	2.5
Broken stone in first-class condition	1.2
Asphalt	1

Serviceability also largely depends on the amount of foothold it offers to horses, provided, however, that the surface friction does not absorb too large a percentage of the tractive force required to move a given load over it. Cobblestones afford an excellent foothold, and for that reason were largely employed between the tracks of the early stone-track roads, and later by horse-car companies for paving between the rails. The resistance of their surface to motion, however, requires the expenditure of about 280 pounds tractive force to move a load of one ton, which makes it unserviceable for many purposes, as compared with asphalt, which affords the least foothold, but requires a tractive force of only about 30 pounds per ton to overcome the resistance it offers to motion.

Comparative safety of pavements.

The materials affording the best foothold for horses, are stated as follows in the order of their merit.*

1. Earth, dry and compact.
2. Gravel.
3. Broken stone (macadam).
4. Wood.
5. Sandstone and brick.
6. Asphalt.
7. Granite blocks.

Observations on the comparative safety of different pavements show that:

1. Asphalt is most slippery when merely damp, and safest when perfectly dry.
2. Granite is most slippery when dry and safest when wet.

* Byrne: "Highway Construction," p. 7.

3. Wood is most slippery when damp and safest when dry.

Granite is, therefore, least safe and wood and asphalt most safe when clean. Slipperiness can be prevented by the sprinkling of sand on asphalt, and gravel on wood, but both make dirt. While the sand tends to wear and damage to the asphalt, the gravel tends to the preservation of the wood.

Durability. The durability or life of the different pavements is given as:

Granite block	12 to 30 years
Sandstone	6 to 12 years
Asphalt	10 to 14 years
Wood	3 to 7 years
Limestone	1 to 3 years
Brick	5 to ? years
Macadam	? years

Cost is always an important question, and while cheapness is placed as the first requirement of an ideal pavement it must be considered in connection with the returns on the investment. The most expensive pavement is not always the best, nor is the cheapest the most economical. The most economical is the one which gives the most profitable returns in proportion to the expenses incurred in its construction and maintenance.

Cost.

"Cheapness" in road-building, as in nearly every other matter, may be false economy. If the first cost is to be charged against the abutting property, the average property owner will look for cheapness without realizing the early destruction of the pavement and the annoyance and expense of endless repairs. A good pavement costs more than a poor one, but it is easier and cheaper to keep in repair, and will last many years longer, while its other economic benefits, comprising greater and easier facilities for traveling, less cost for repair to vehicles, less wear on horses, saving of time, and the ease and comfort of those using it, will much more than compensate for the extra expense involved in building it.

PART II

COUNTRY, SUBURBAN, AND MISCELLANEOUS ROADS

CHAPTER IV

LOCATION OF COUNTRY ROADS

The problems involved in the construction of country roads are quite different from those connected with similar operations on city pavements, and may in general, be divided into three periods:

1. Locating, or laying out, the route;
2. Making the roadbed;
3. Making the road surface.

The location of country roads is the scientific determination of the most suitable route and gradients for the proposed line of communication. In the earliest days or in the early days of new settlements, routes were made according to the line of least resistance, and without regard to any considerations other than the easiest method of traveling, or of conveying goods, from one place to another.

Length of straight and curved roads.

The Romans, at very great expense, built their roads uphill and down hill, through swamps and forests, and over all obstacles, in perfectly straight lines, in the belief that this was the shortest distance between two points and constituted the best location. Theoretically they were right, but practically they were correct to a very limited degree, for a straight road over a hill is not necessarily any shorter than a curved road around it. Both

a. Before Improvement.

b. In Process of Construction.

c. The Finished Road.

Fig. 3.—The Evolution of a Country Road.

are curved, one in its vertical and the other in its horizontal plane, and they may be precisely the same length, but the one over the hill is said to be straight, only because its vertical curvature is less apparent to the eye.

Comparative advantages of straight and curved roads.

Of the two roads of equal length, the route over the hill has the disadvantages of greater first cost, greater maintenance expense, greater damage from rains and other causes, greater wear on horses and vehicles in the haulage of goods over it, and consequently greater cost to those using it. But even if the level, curved road were much longer than the straight and steep one, the former would, as a rule, be the more economical on account of the ease of travel over it. "Straightness" in a country road is frequently overrated, and efforts to obtain it involve in many cases injury to the beauty of the road and of the landscape, with no compensating economic advantages.

Economy the basis of location.

Economy forms the true basis of proper location; that is, ultimate economy in making the route as direct and, subject to drainage requirements, as level as practicable, in achieving the best results at the least present and future expense.

Too much "economy" should not, however, be urged in the work of location. There is an old saying: "Nothing pays like first cost in road-building," meaning simply that money expended in intelligent study of the location is the most economical expenditure in the construction of a road. The importance of the selection of the best route cannot be too strongly urged, because an error made in this first stage of roadmaking will cause a heavy expense for rectification, and, until rectified, imposes a perpetual tax upon the public for maintenance.

Value of scientific road location.

Gillespie in his book on roads (1847) gives a forcible instance of the value of road improvement by scientific location. An old road in Anglesea, North Wales, rose and fell between its two extremities, a distance of 24 miles, a total perpendicular amount of 3540 feet, while a new road, laid out by Telford between the same

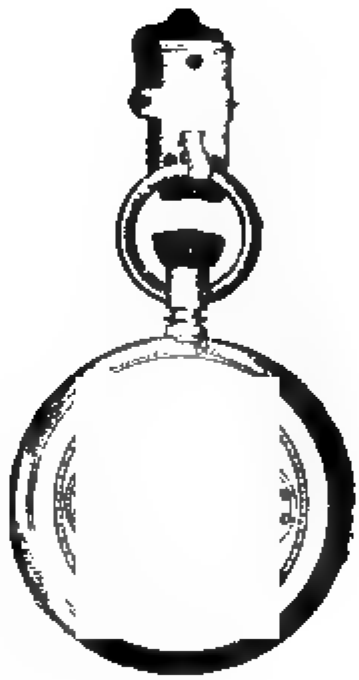
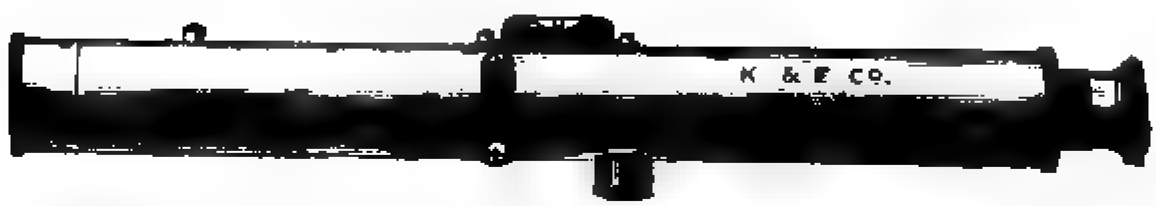


FIG. 4.—Pocket Compass, with folding sights.

FIG. 7. Pedometer.

FIG. 5.—Aneroid Barometer.

FIG. 8.—Odometer.



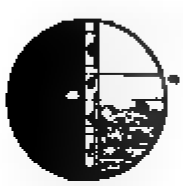


FIG. 6.—Hand Level.

Instruments used in Location.

points, not only reduced the road distance to 22 miles, but also reduced the rise and fall to only 2257 feet. Thus, 1283 feet of perpendicular height was done away with which every horse passing over the road had previously been obliged to ascend and descend with its load.

Methods employed in location.

The principles observed and the methods employed in the location of a road are substantially the same as used in the location of a railroad. Hard and fast rules cannot be laid down, for each road must be designed for the place it is to occupy and the service it is to render, and is dependent upon many local conditions, as well as upon the topographical features and the nature and extent of the traffic that it may develop. The problem involves considerations of distance, grades, curves, width, and the establishment of controlling points, and always presents an opportunity for the exercise of the most careful judgment.

To obtain the requisite data regarding these points upon which to form his judgment, the engineer must study maps of the district and must make a personal reconnoissance, or examination, of the tract to be traversed, by either riding or walking over it, and carefully noting its principal physical contours and natural features, the immediate object being to select one or more trial lines, from which the final route may be ultimately determined.

Characteristics of country noted.

In making this reconnoissance, a knowledge of physical geography is essential. Among the characteristics of the country noted are:

1. Inclinations of the strata and their nature and conditions as to dryness.
2. Extent to which the surface of the road will be exposed to the action of the air and the rays of the sun.
3. Location of crossings of valleys, rivers, and passes.
4. Condition of river beds, with a view to secure stable foundations for bridges, etc.
5. Sources, accesses, and distances of the supply of material for structural works, such as retaining walls, etc., and for stones suitable for road covering.

Fig. 9.—Contour Lines.

6. Levels of all existing lines of communication, such as railways, roads, canals, and of rivers and streams.

The instruments used in the reconnoissance are:

1. Compass, for ascertaining the direction.
2. Aneroid Barometer, for fixing approximate elevation of summits.
3. Hand-level, for measuring slopes.
4. Odometer, or Pedometer, to determine the distance, the former for use with a vehicle and the latter for use in walking, but if these instruments cannot be used, the distance can be approximated closely enough for preliminary work by various other means.

Instruments used.

The irregularities of the surface of the ground are laid out on paper by means of "contour lines"—fine lines traced through the points of equal level over the surface surveyed, denoting that the level of the ground throughout the whole of their course is identical; that is to say, that each part of the ground over which the line passes is at a certain height above a known fixed point, this height being indicated by the figures written against the line. These lines, by their greater or less distance apart, have the effect of shading, and make apparent to the eye, the undulations and irregularities in the surface of the country.

Contour lines.

A map is then made showing the topography of the district —the length and directions of the proposed line; the rivers, watercourses, roads and railroads; town, county and property boundary lines, and any other matters of interest. The nature of the soil; character of excavations; width, depth and velocity of rivers; character of banks and bottom, and other features and figures that cannot be shown on a map or profile, are given in an accompanying "memoir."

Topographical map.

Levels are taken along different lines, at regular intervals, and heights of all objects that may affect location are noted, and "bench-marks"* are established. From these levels, a profile, or longitudinal section

Levels and bench marks.

* Reference marks made on fixed objects, such as gate posts, houses, trees, etc.

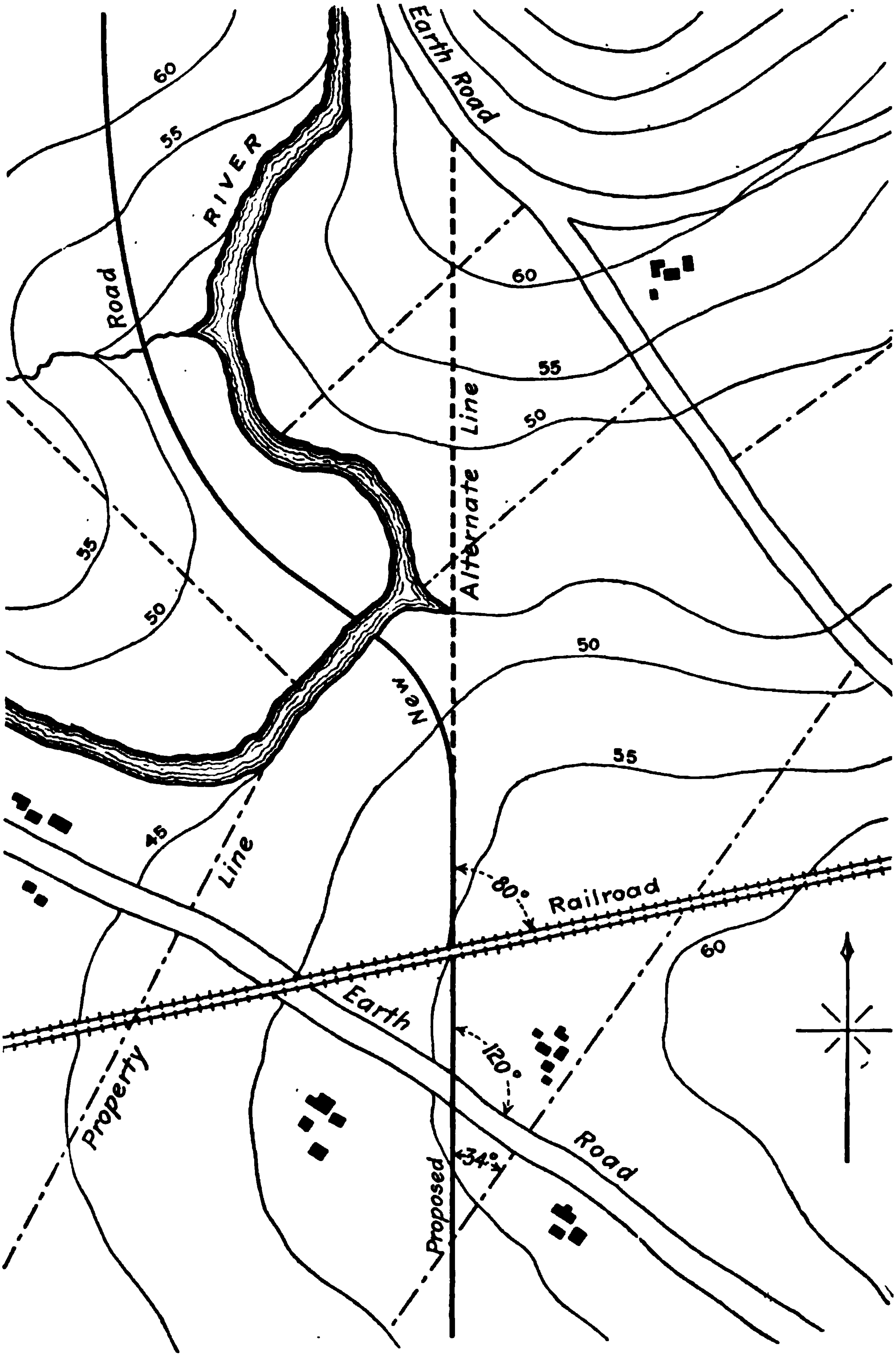


FIG. 10.—Topographical Map.

of the proposed route is made, on such a scale that it will show with distinctness the inequalities of the ground.

Value of saving distance.

In regard to the saving of distance, the value is quite evident where the road is so situated that it would enable teams to make an additional trip per day in the hauling of freight. But where the traffic is of a more indefinite nature, or the saving proposed is insufficient to admit of additional trips, this value depends upon the value to other work of the small portion of time of men and teams which may be saved by the shorter route—a value which exists, but is difficult to estimate.

There are other points of value in the saving of distance, which may be summed up as follows:

1. The advantage to the community of bringing various points closer together, such as bringing two towns into closer relations or bringing country property nearer to markets.

2. Variation due to the character of the road surface: as the cost of transportation is less over a smooth than over rough surface, the value of reducing distance is also less on the smooth surface.

3. Variation due to gradient: on a road where the ruling gradients are steep the value is greater than upon one with light gradients, because of the greater number of loads necessary to move traffic.

4. The cost of maintenance of a road may be considered, like the costs of transportation, to be directly proportional to the length of road, and a saving of distance involves a saving in cost of maintenance.

Grades.

There are two kinds of grades: Maximum and Minimum. The "Maximum Grade" is the steepest which is permissable and the "Minimum Grade" is the least allowable for good drainage.

A level road is desirable and preferable, but as it can seldom be obtained, the roadbuilder must investigate the effects of grades upon the cost of construction and maintenance, and also determine the most suitable grade under the special conditions.

Methods of overcoming grades.

Where there is a grade to be overcome, it can be reduced by (1) going around the hill; (2) zig-zagging up the slope; (3) cutting through the hill. In the case of a long slope, the first or second must be employed, but if the grade is short, the third method is usually the cheapest.

FIG. 11.—A poorly located road; by turning to the right a gentle grade could have been secured and the two bad hills avoided.

Determination of maximum grade.

The determination of the proper maximum, or ruling, grade is important and is governed by two considerations; one relating to the power expended in ascending, and the other to the acceleration in descending, the incline. As an ascent, it concerns the draft of heavy loads; as a descent, it mainly concerns the safety of rapid traveling.

Men and animals can ascend steeper slopes than they can descend. A man walks slowly up-hill and quickly down-hill. A horse does the reverse; the steeper the ascent, the faster he attempts to travel, while in descending he moves at a slow trot which gradually subsides into a walk. Consequently the inclination which admits of high speed in descending practically controls the maximum grade.

This will depend upon (1) the class of traffic that will

use it, whether fast or slow, heavy or light; (2) the character of the pavement adopted; (3) the cost of construction. It is evident, therefore, that no fixed maximum gradient can be adopted to suit all conditions. Experience has shown that for fast and light traffic, the maximum should not exceed 2 per cent, or 1 in 50; for mixed traffic, 3 per cent, or 1 in 30, may be adopted; for slow traffic, combined with economy, 5 per cent, or 1 in 20, should not be exceeded.

For bicycle travel a 2 per cent grade can be ascended with comparative ease and descended with little effort. Heavier grades, up to 5 per cent, can be ascended by the average bicycle rider without extremely arduous effort and descended without serious danger, but grades above 5 per cent are too steep for ascent with comfort or descent with assured safety.

For pleasure driving the grade, when practicable, should not exceed 4 per cent. A good horse with a light carriage and two persons will trot easily up a 4 per cent grade and as easily down without a brake. With a higher gradient the strain in either direction becomes increasingly apparent. For freight traffic the maximum grade admissible is 12 per cent.

Most suitable maximum grades.

The maximum grades established by experience for various paving materials are approximately:

For stone blocks	All grades
" wood and brick	5 per cent, or 1 in 20
" broken stone	3 per cent, or 1 in 30
" asphalt	$2\frac{1}{2}$ per cent, or 1 in 40.

The maximum adopted by the French engineers is 1 in 20, while that adopted in England by Telford was 1 in 30.

It does not follow, however, that the maximum grade is the most advantageous grade. To determine the latter, every element that affects the cost of transportation must be considered. It is dependent upon the amount of traffic, and the cost of construction and maintenance of the highway, and has been found by experiment to be approximately:

Most advantageous grade.

For mountainous country, between	1/20 and 1/30	
" hilly country, between	1/30 and 1/40	
" level country, between	1/40 and 1/50.	

Establishment of minimum grade.

The establishment of a minimum grade is also necessary, as well as economical, in cost of maintenance. All roads should be higher in the center than at the sides in order to shed the rain into the side ditches, but even on the best roads longitudinal ruts are liable to form from excessive use or neglect of proper maintenance, and these seriously interfere with the surface drainage. If the road were perfectly level, every rut would hold water, which would soon soak into and damage the road, whereas with even a slight grade, every rut and wheel track becomes a channel to carry off the rain water.

The minimum grade established in England is 1 in 80, or 1¼ per cent; in France it is 1 in 125, or .8 per cent, which may be adopted as a minimum, and in a flat country, the roads should be artificially formed into gentle undulations approximating this minimum limit. In the United States it is 1 in 200, or .5 per cent.

Establishing the final grade.

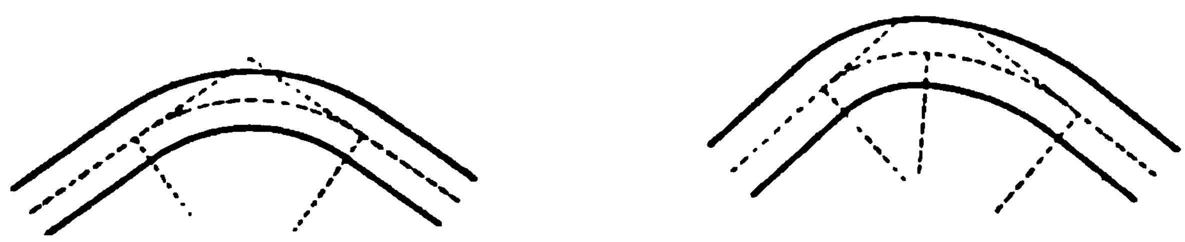
When the profile has been made a grade line is drawn upon it in such a manner as to follow its general slope, but to average its irregular elevations and depressions. If the ratio between the whole distance and the height of the line is less than the maximum grade intended to be used, this line will be satisfactory; but if it is steeper, the cuttings or the length of the line will have to be increased—preferably the latter, by means of curves.

Curves.

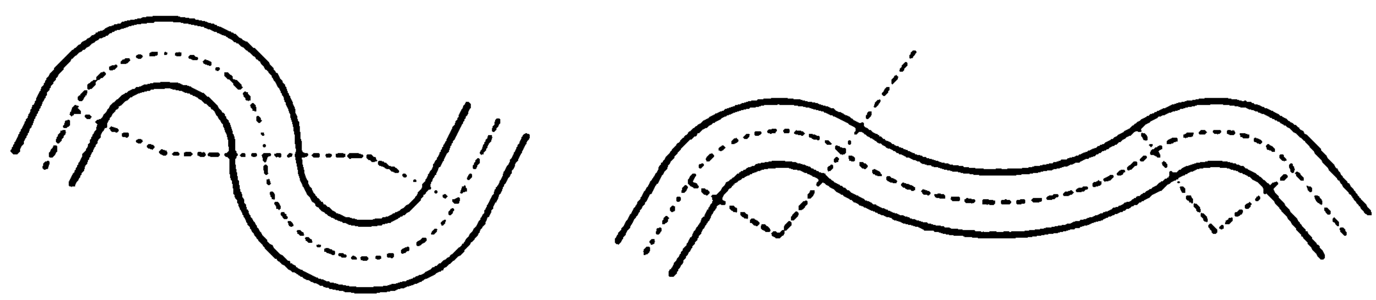
As regards curves in roads, no fixed rules can be laid down. The greatest radius possible should be employed, depending upon the width and location of the roadway and the character of the traffic, but it should not be less than 100 feet for a 12-foot road, 75 feet for a 16-foot road, of 66 feet for an 18-foot road. In France, country roads of 20 feet width have a radius of 50 feet; in Germany, it is 40 feet.

When the curve occurs on an ascent, the grade at that place must be diminished in order to compensate for the additional resistance of the curve. Curves may be built circular or parabolic, the latter preferable when possible, and the width of the wheelway should be increased to permit the swinging of teams and to prevent accidents.

Curves on an ascent.



a. Simple Curve. *b*. Compound Curve.



c. Reverse Curve. *d*. Double Reverse Curve.

FIG. 12.—Types of Curves.

Excessive crookedness should be avoided on account of expense of construction and maintenance and of the extra time and labor necessary in traveling over the road. Partly on these grounds and partly on the grounds of its dangers and its inconvenience as regards drainage, etc., a zig-zag method of surmounting a hill should be avoided.

The width of a road depends upon the amount and nature of the traffic to be accommodated, and cannot be standardized. Wide roads are best as they expose a larger surface to the drying action of the sun and wind and require less supervision than narrow ones, but the first cost is greater and in country districts they are not necessary. In many places a roadway just wide enough for a single team is all that is required. In cases of more frequently used roads, the minimum width should allow two teams to pass with safety, but in all cases the width of land appropriated for highway purposes—the "right of way"—

Width of roadway.

should be sufficient to provide for future increase in traffic. On main country highways, this width should allow for a double roadway—a paved center and a natural earth road at the side.

Some of the most common widths of roadways and rights of way are:

	Right of way.	Roadway.
United States	49½ to 66	16
England	66	20 to 22
Holland	38	14
France: National roads	66	22
Departmental roads	40	20
Provincial roads	33	20
Neighborhood roads	26	16

One of the most important points in location is the selection of suitable bridge sites. These are sometimes restricted to a certain point, but if not, the best possible site is determined and the location of the road is made subordinate to it. In this selection consideration must be given to

Selection of bridge sites.

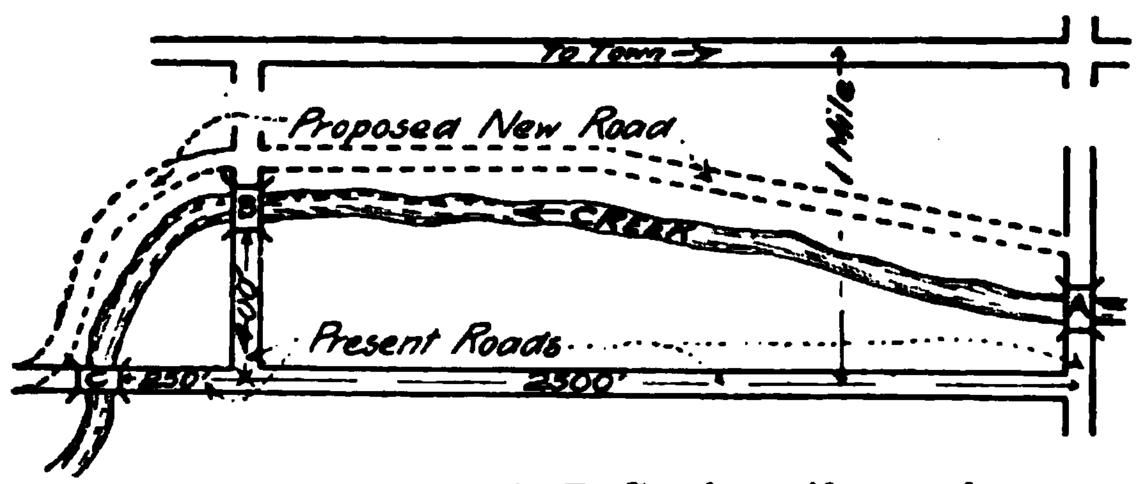


FIG. 13.—Showing three bridges, A, B, C, where if a road were put in as shown by the dotted lines only the bridge at A would be needed, and the public convenience would be served just as well as with the present arrangement.

1. The character of the river bed, in order to obtain the best foundation.

2. Stability of the river banks.

3. Straightness or curvature of the river, so that the bridge may be at right angles to the stream-flow and if possible, over a straight stretch of the stream.

In making the final selection of a route, some of the basic principles to be observed are:*

Principles to be observed in final selection.

1. To follow the route which affords the easiest grade.

2. To connect the places by the shortest and most direct route commensurate with easy grades.

3. To avoid all unnecessary ascents and descents.

4. To give the center line such a position with reference to the natural surface of the ground that the cost of construction shall be reduced to the smallest possible amount.

5. To cross all obstacles, where structures are necessary, as nearly as possible at right angles.

6. To cross ridges through the lowest pass which occurs.

7. To cross either under or over railroads and to avoid grade crossings.

Stakes are placed at intervals along the route, indicating

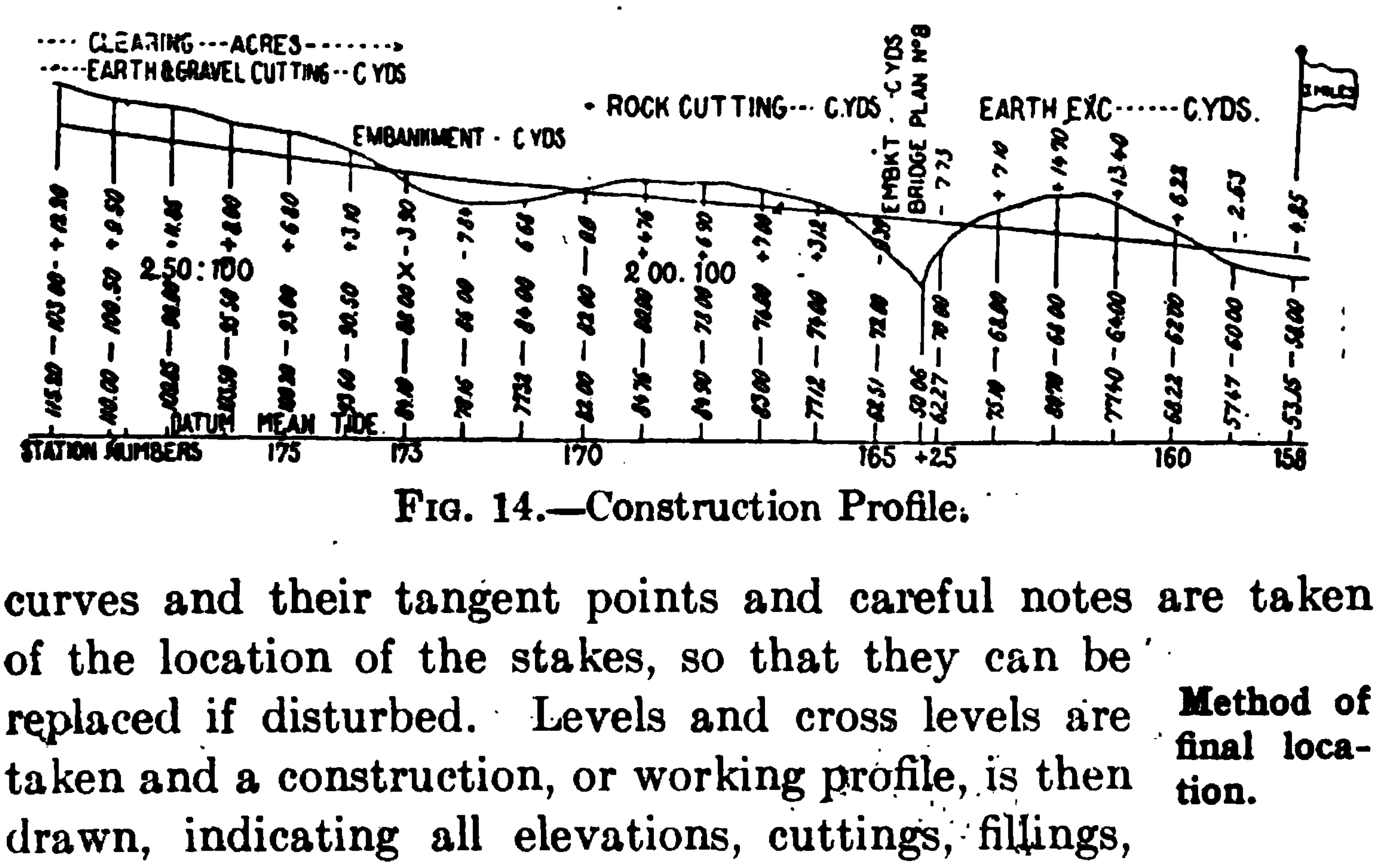


FIG. 14.—Construction Profile.

curves and their tangent points and careful notes are taken of the location of the stakes, so that they can be replaced if disturbed. Levels and cross levels are taken and a construction, or working profile, is then drawn, indicating all elevations, cuttings, fillings, embankments, bridges and other features necessary to permit making an estimate of the work.

Method of final location.

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* Byrne: "Highway Construction," p. 460.

FIG. 15.—A Costly Piece of Grading.

CHAPTER V

CONSTRUCTION AND PROTECTIVE WORKS

UNDER this head may be included such works connected with the construction of the roadbed, as earthwork, foundations, bridges, culverts and retaining walls.

EARTHWORK

The term "Earthwork" embraces all operations performed in the making of the excavations and embankments to prepare them for the road covering, such as the reduction of gradient upon steep inclinations, by cutting and filling, and the making of better drainage by raising the road across low ground. In its broadest sense and as generally understood, "earthwork" includes work in rock as well as in the looser materials of the earth's crust, and for purposes of comparison, may be classified with regard to the ease or difficulty with which it can be excavated, as follows:

Classification of earthwork.

1. Earth, including loam, clay, sand, and loose gravel. This may be further classified approximately as: *a*. Easy ground, *b*. Average ground, *c*. Hard ground.
2. Hardpan, including cemented gravel, slate, cobbles and small boulders, and other materials of a compact earthy nature.
3. Loose rock, including shale, decomposed rock, boulders and detached masses of rock, and other material of a rock nature that may be loosened with a pick.
4. Solid rock, including all rock found in place in ledges and masses, and large boulders which can be removed only by blasting.

In selecting the final location and gradient of the road, the engineer must take into consideration the "equalizing" or "balancing" of the earthwork, so that the material taken from a cutting may, as nearly as possible, and consistent with the distance and cost of haulage, be sufficient to form an embankment. This redistribution of the earthwork along the line of the road is in many cases essential to economy in the cost of the work, as a surplus of cutting or filling involves either waste or borrowing, both of which cause additional expense for labor and land. If there is a surplus of cutting, the waste earth is disposed of in convenient banks adjoining the work, termed "spoil-banks." If, on the other hand, there is an excess of embankment requirements over the supply from cuttings, the deficiency is obtained either by widening the excavations or from an excavation termed a "borrow-pit," made in the vicinity of the embankment. Sometimes, however, the location of cuts and fills makes it more economical to either waste the earth or to borrow it, than to haul it any considerable distance.

Equalizing earthwork.

When the road lies along the side of a hill, this balancing, termed in this case, "transverse balancing" is accomplished by locating the center line of the road so that the cutting from one side will form the embankment on the other, unless the side slopes are very steep, when it is better to make the road mostly in cuts on account of the difficulty of forming stable embankments on steep slopes.

Transverse balancing.

The problem of balancing earthwork is a very important one in practice, for upon its mode of solution depends a large portion of the cost of the work. The most economical use of the material depends on the machinery used in moving the earth; the character of the earth; the road over which it is to be transported; the cost of labor and land, and other conditions, all of which must be taken into consideration by the engineer in deciding what is best for each particular case.

In making excavations or forming side slopes, it is necessary to insure stability and prevent slipping or sliding of its parts

on each other by giving proper consideration to the "natural slope" of the material used. This is the slope assumed by the face of a mass of earth after considerable exposure to the elements, at which the earth, by friction alone, will have perfect stability. The angle made by this slope with the horizontal is the "angle of repose," or the "angle of internal friction." Loose earth will remain in equilibrium with its face at this slope; if piled at a greater slope, cohesion will hold the face at this greater slope for a time, but the earth will soon crumble and slide down until the angle of repose is attained. This angle depends on the nature of the soil, the action of the atmosphere and of internal moisture, being approximately as follows:

Natural slope of embankments.

Compact earth	50°	¾ : 1
Rubble	45°	1 : 1
Clay (well drained)	45°	1 : 1
Gravel	40°	1¼ : 1
Shingle	39°	1¼ : 1
Dry sand	38°	1¼ : 1
Vegetable earth (Loam)	28°	1¾ : 1
Wet sand	22°	2½ : 1
Clay (wet)	16°	3 : 1

For all practical purposes it may be said that in both excavation and embankment, earth, sand and gravel stand at a slope of 1½:1, or 33° 41″.

The natural and strongest form of earth slopes is a concave curve, with the flattest portion at the bottom, but this form is seldom given to the slopes in construction, as straight or convex forms save excavation by the contractor, and will continue to slip until the natural form is attained. Figs. 16 and 17 show the contours of embankment and excavation which have met with the most general approval of the engineering profession. While it is not usual to employ artificial means to protect the surface from the action of the weather, it will be an ultimate economy in keeping the roadways in order, if the side-slopes are sown with grass-seed, as the roots

of the grass bind the earth together and prevent slipping, which is usually caused by the saturation of the earth with water.

When the earth is first thrown up by a shovel, without breaking down the clods, or artificial consolidation of any sort, it occupies more space than it did in place, but after being placed in embankment, it subsides or shrinks, until it occupies less space than in the pit from which it was taken, the amount of this shrinkage depending on the method of compacting.

Shrinkage of earthwork.

When it is considered that the earth in embankment is not so hard and firm as in its original position, and that it will settle still further after the embankment is finished, this

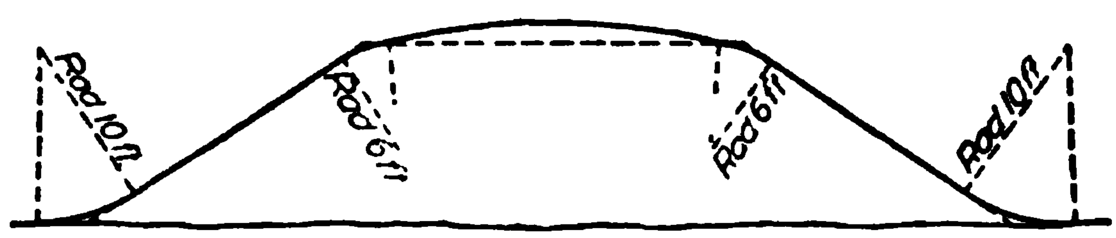

Fig. 16.—Cross-section for Embankment.

Fig. 17.—Cross-section for Excavation.

"shrinkage of earthwork" may seem strange, but may be accounted for by the following facts:*

1. The continued action of frost has made the soil in its natural position more or less porous.
2. Earth which has been lying *in situ* for centuries becomes more or less porous through the slow solution of their soluble constituents by percolating water.
3. The surface soil in rendered more or less porous by the penetration of vegetable roots which subsequently decay.

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* "Roads and Pavements," I. O. Baker, page 91.

4. There is ordinarily more or less soil lost or wasted in transporting it from the excavation to the embankment.

From the many experiments made to obtain exact data regarding this shrinkage, the following general rules or principles have been deduced: *

1. Taking extreme cases, earth swells when first loosened with a shovel, so that after loosening it occupies $1\frac{1}{7}$ to $1\frac{1}{2}$ times as much space as it did before loosening; in other words, loose earth is 14 per cent to 50 per cent more bulky than natural bank earth.

2. As an average we may say that clean sand and gravel swell $\frac{1}{7}$, or 14 to 15 per cent; loam, loamy sand or gravel swell $\frac{1}{5}$, or 20 per cent; dense clay, dense mixtures of gravel and clay swell $\frac{1}{3}$ to $\frac{1}{2}$, or 33 to 50 per cent, ordinarily about 35 per cent, while unusually dense gravel and clay banks swell 50 per cent.

3. That this loose earth is compacted by several means; (*a*) the puddling action of water, (*b*) the pounding of hoofs and wheels, (*c*) the jarring and compressive action of rolling artificially.

4. If the puddling action of rains is the only factor, a loose mass of earth will shrink slowly back to its original volume, but an embankment of loose earth will at the end of a year be still about $\frac{1}{12}$, or 8 per cent greater than the cut it came from.

5. If the embankment is made with small one-horse carts, or wheel scrapers, at the end of the work it will occupy 5 to 10 per cent less space than the cut from which the earth was taken, and in subsequent years will shrink about 2 per cent more, often less than 2 per cent.

6. If the embankment is made with wagons or dump cars, and made rapidly in dry weather without water, it will shrink about 3 per cent to 10 per cent in the year following the completion of the work, and very little in subsequent years.

7. The height of the embankment appears to have little effect on its subsequent shrinkage.

8. By the proper mixing of clay or loam and gravel, followed by sprinkling and rolling in thin layers, a bank can be made weighing $1\frac{3}{4}$ times as much as loose earth, or 133 pounds per cubic foot.

9. The bottom lands of certain river valleys and banks of

* "Earthwork and Its Cost," by H. P. Gillette, page 17.

cemented gravel or hardpan are more than ordinarily dense and will occupy more space in the fill than in the cut unless rolled.

The natural shrinkage of the ordinary soils is in the following order, beginning with the least: (1) sand and sandy gravel, (2) clay and clayey soils, (3) loams; and according to the method of handling: (1) dragscrapers, (2) wheelscrapers, (3) wagons, (4) cars, (5) wheelbarrows.

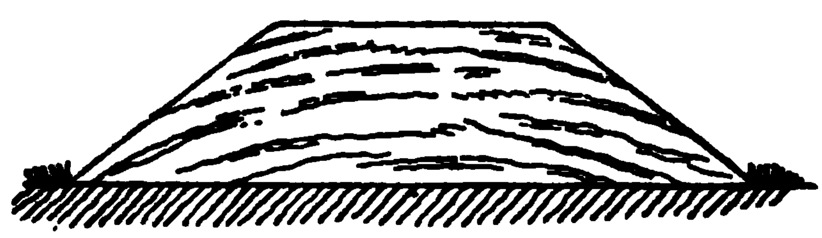


FIG. 18 shows an embankment made in the customary manner by dumping material mainly in the center of the roadway and sloping it to the right and left by the usual means, leaving it always higher in the center and with a tendency to slide off at both sides.

Making embankments.

In making embankments, materials are used which have the greatest frictional stability, such as rock, shingle, gravel and clean sand; wet clay and mud are entirely unsuitable. The cheapest and quickest method of building the embankment is by making it of a single layer, but in certain special cases, such as filling in behind a retaining wall and bridge abutments, the embankment is

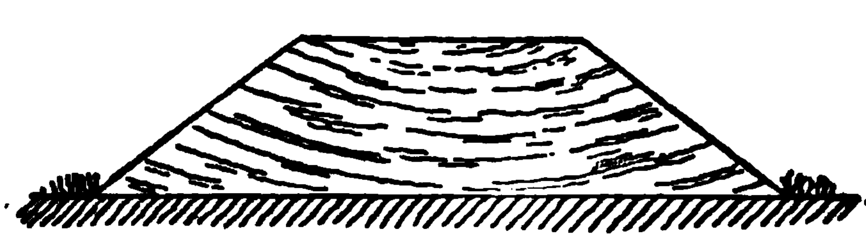


FIG. 19 shows the method in which the material has been deposited properly and the surface kept hollowed until finished.

made in thin horizontal layers, 9 to 18 inches deep, each rolled and rammed down so as to make it compact and firm before laying down the next layer.

Specifications usually require that "all matter of vegetable nature be carefully excluded from the embankment," but this is sometimes impracticable. It is desirable that all stumps, weeds, brush, etc., are removed from the space to be

occupied by the embankment as well as all deposits of soft compressible matter, in order to give it a firm base and to permit it to bond with the earth below. To overcome the tendency to spread, a small trench is sometimes excavated

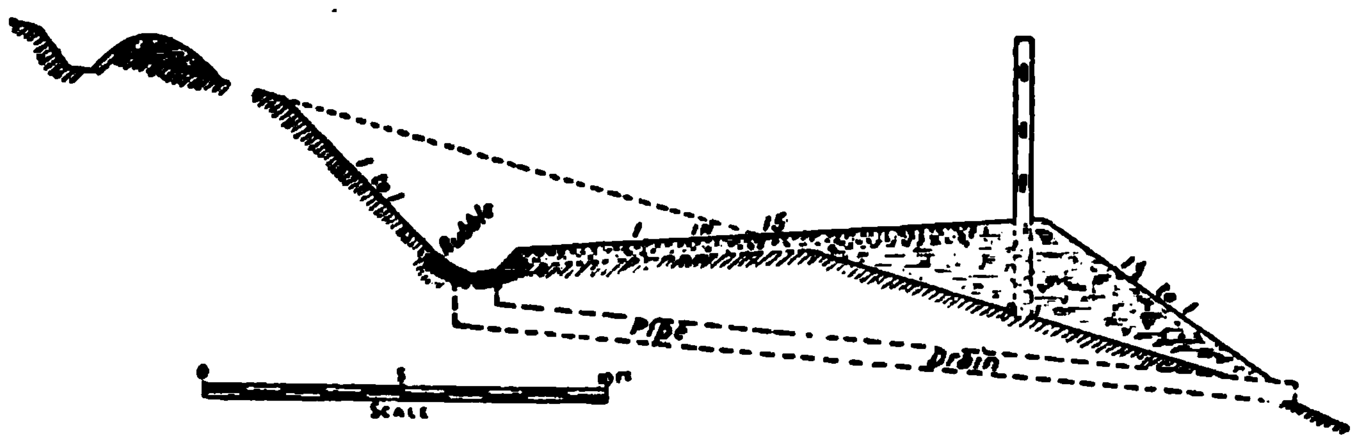


Fig. 20.—Method of Construction on Slopes by Embankment.

along the foot of the embankment, or it may be buttressed with a low stone wall.

When a roadway is built on the side slope of a hill, partly by excavating and partly by embanking, the most common method is to build the embankment out gradually along the whole line of the excavation. This, however, is insecure,

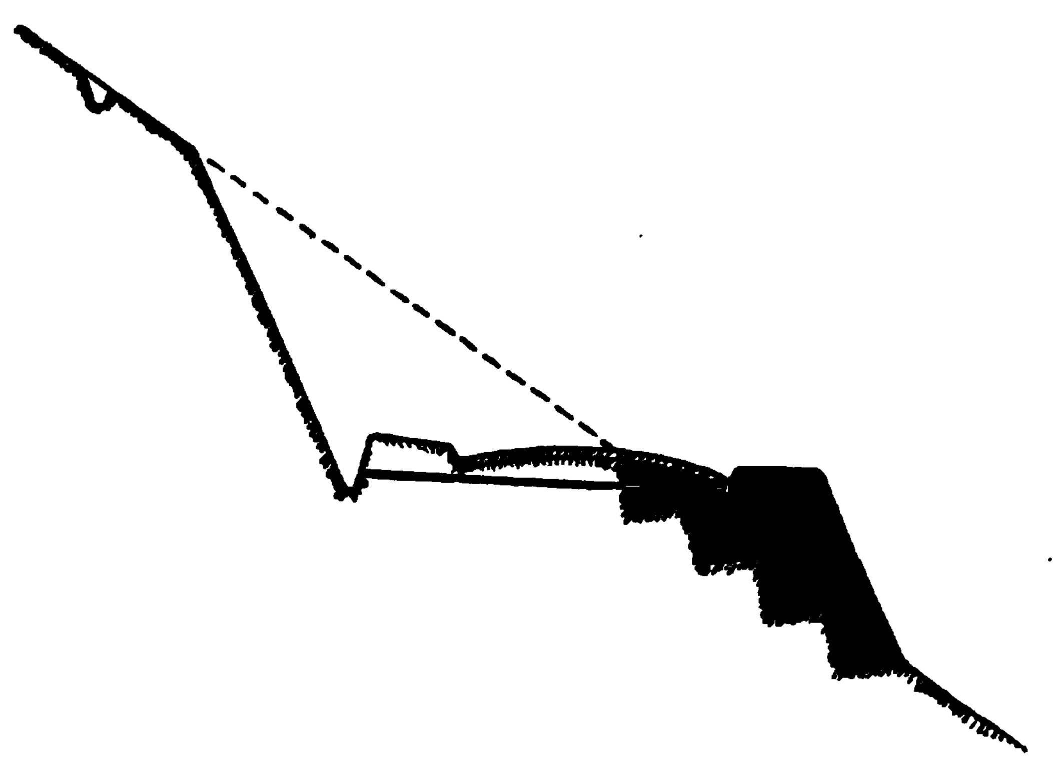


Fig. 21.—Method of Construction on Slopes by Stepped Embankment.

as the excavated material, if simply deposited on the natural slope, is liable to slip. It should be given a secure hold, particularly at the foot of the slope, by cutting the natural surface into steps perpendicular to the axis of greatest pressure.

But on side hills of great inclination, retaining walls must be substituted for the side slopes of both the excavations and the embankments (see page 88).

On rock slopes where the inclination of the natural surface is not greater than 1:2 the road may be constructed partly in excavation and partly in embankment in the usual manner

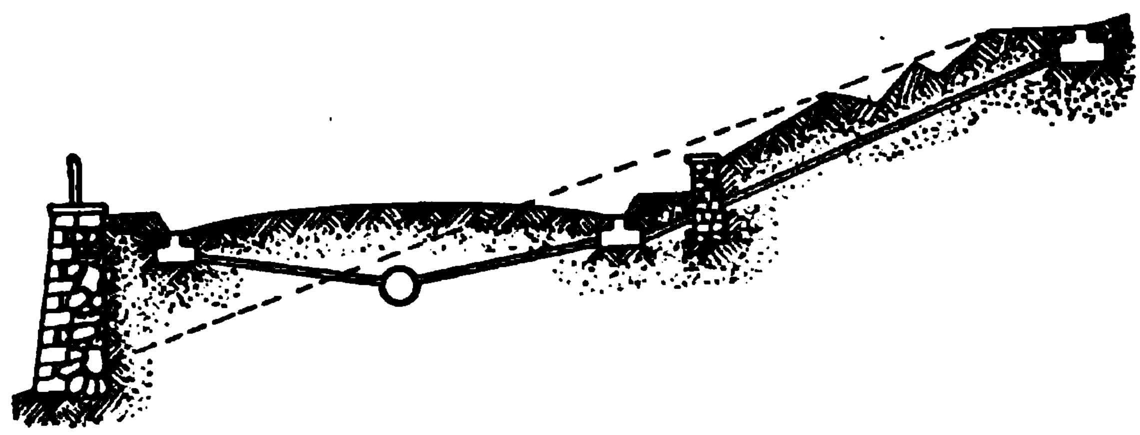


FIG. 22.—Method of Construction on Slopes, using Retaining Walls.

as outlined, but when the rock slope has a greater inclination than 1:2 the whole of the roadway should be in excavation as shown in Fig. 24. Roads on rock slopes may also be built in the form of a platform on timber frameworks supported by beams and struts.

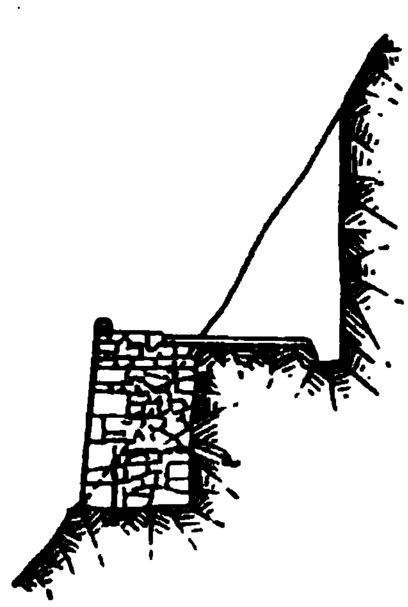


FIG. 23.

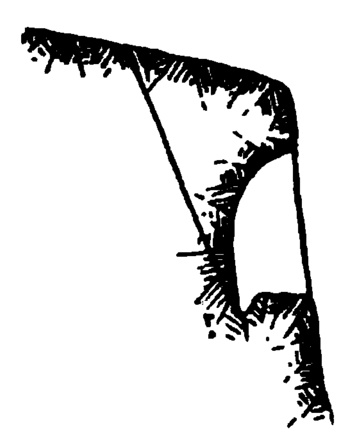


FIG. 24.

Method of Construction on Rock Slopes.

In constructing embankments across wet and unstable ground it is frequently necessary to form an artificial foundation upon which to place the earth embankment. This may be accomplished in some cases by excavating a little of the soft material and substituting sand or gravel, or in other cases it may be advisable to employ layers of brushwood or

fascines as a support for the embankment. Sometimes it may be possible to drain the soft material by deep ditches, so as to render it capable of sustaining the road, and in all cases drainage should be provided in so far as possible to make the embankment more secure.

(From Coane's "Australasian Roads")

FIG. 25.—Road entirely in Rock Cut Hawk's Crag, Buller Gorge, New Zealand.

Cost of earthwork.

Earthwork is paid for by the cubic yard, usually measured "in place," that is, in the natural bank, cut, or pit, before loosening, the cost being based on the daily wages of a common unskilled laborer. This cost may be divided into three parts:

1. Cost of loosening the earth, depending on the kind of earth to be handled.
2. Cost of transport, depending on the quantity of material to be moved, the distance of haulage and the kinds of roads over which it must be hauled.
3. Cost of transforming the transported earth into the desired shape.

It is necessary, therefore, to study the various methods of loosening and handling the various kinds of materials and their costs, and the relative economy of moving earth with a shovel, or transporting it by wheelbarrow or horse cart, which involve more questions than could be taken up satisfactorily within the limits of a few pages.

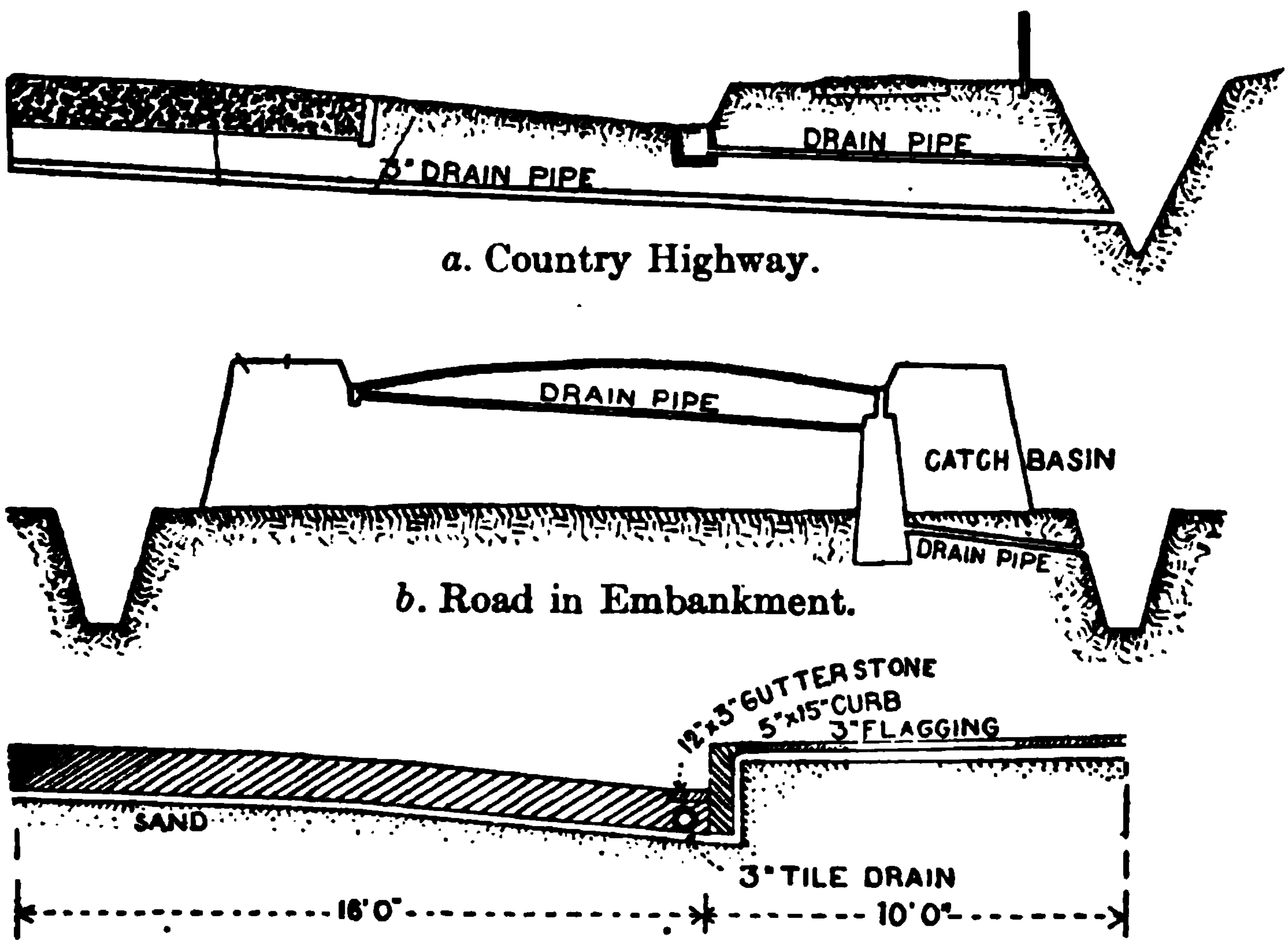
The calculation of earthwork forms a large part of the necessary labor of the engineer, and to relieve him of the tediousness of this work, as well as to facilitate its operation, many tables, diagrams, and approximate formulæ have been devised, no one of which has, however, met with general favor by engineers. Several publications dealing with these methods of calculations are listed in the bibliography in Appendix V.

Foundation and Drainage

In building any roadway, whether for the city or the country, for light or heavy traffic, two of the most important points to be considered are drainage and foundation.

Theoretically, the foundation should last forever, and the sole cost of maintenance should be borne by the wearing surface, but this, for economical reasons, is difficult of realization. The light traffic roadway of to-day, requiring for foundation only four inches of broken stone, may be the heavy traffic street of to-morrow, requiring six inches of Portland cement concrete. The advent of the pleasure and the industrial automobile is bringing upon the macadam roads of the country far greater weight than was imagined by the original builders of these roads, and it is only a question of time when it may be necessary to reconstruct many of these roadways from the bottom up with a firm concrete foundation.

In building new roads, future traffic should be taken into account, and a foundation sufficient for all reasonable development should be provided. The stability of the road surface depends upon the foundation and this in turn largely depends upon the facilities provided for drainage. While proper



a. Country Highway.

b. Road in Embankment.

c. Suburban Street.

Fig. 26.—Methods of Drainage.

attention may be given to surface drainage by providing sufficient crown to shed the water and ditches to carry it away, the importance of subdrainage is often overlooked. Its necessity must be realized, as a permanent foundation can be secured only by keeping the subsoil dry; unless this is done, and water is kept out of the foundation, sooner or later it will destroy the superstructure. Most earths, when kept dry, form a strong foundation, but when the ground is naturally wet a good road cannot be constructed without proper subdrainage, as the earth loses its sustaining power and the formation goes to pieces. Where the soil, however, is sandy or calcareous, or

The importance of drainage.

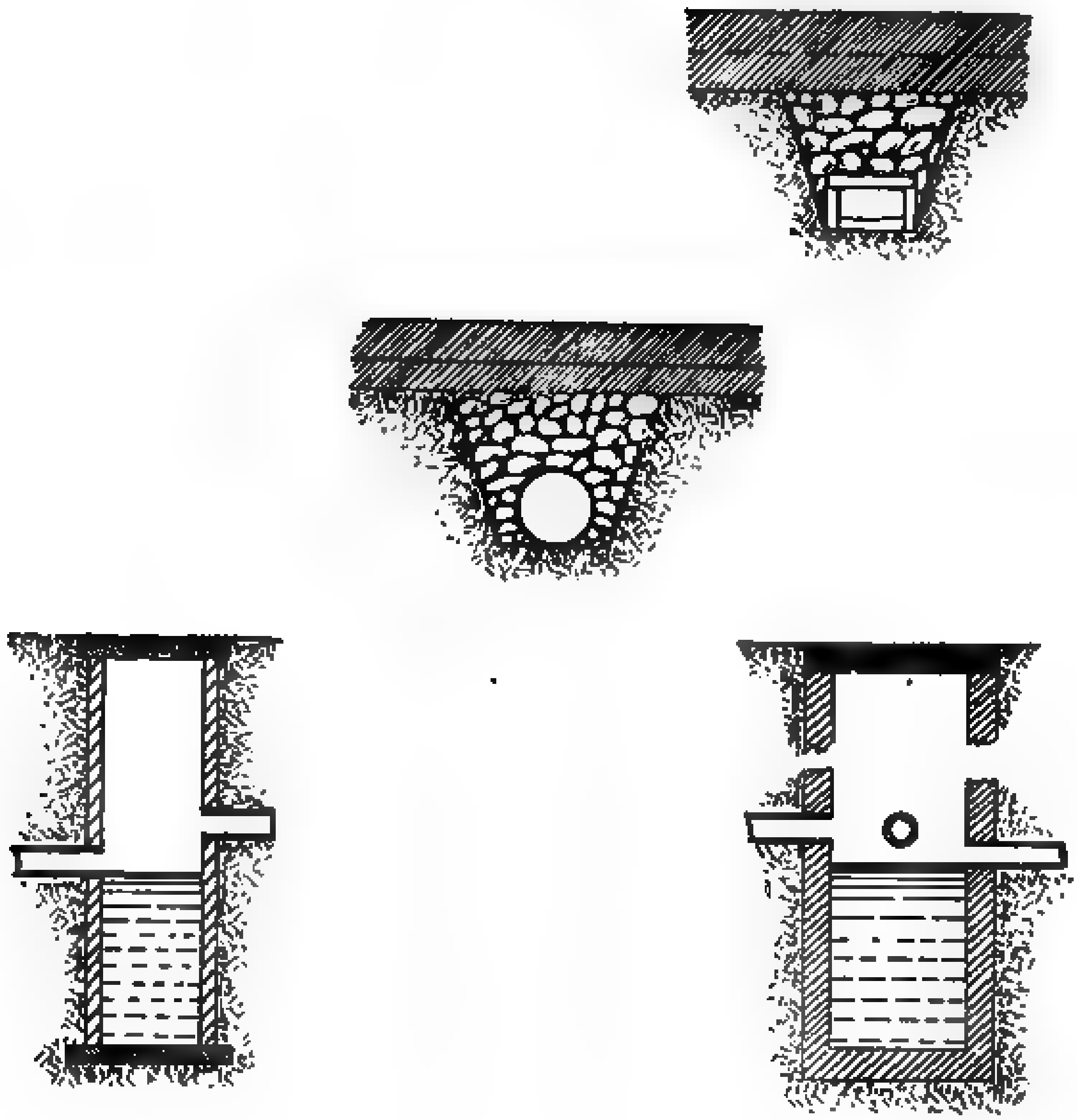


Fig. 27.—Types of Drains.

Pole Drain	Blind Drain	Stone Drain
Silt Basin	Tile Drain	Silt Basin
	Outlet	

where the subsoil consists of fairly open gravel, underdrains are seldom, if ever, required.

Drainage is especially important upon earth roads, because the material of the road surface is more susceptible to the action of the water, and more easily destroyed by it than are the materials used in the construction of the better class of roads. When water is allowed to stand upon the road in ruts and hollows, the earth is softened and readily penetrated by the wheels, which continually deepen and enlarge the ruts until the whole crust of the road and the subsoil beneath is weakened. The action of frost is also apt to be more disastrous upon the more permeable surface of the earth road, having an effect to swell and heave the roadway and throw its surface out of shape. It may, in fact, be said that the whole problem of the improvement and maintenance of ordinary country roads is one of mere drainage. A road on a wet undrained bottom will always be troublesome and expensive to maintain, and it will be economical in the long run to go to considerable expense in making the drainage of the subsoil as perfect as possible.

There are three systems of drainage: underdrainage, side ditches, and surface drainage:

Systems of drainage.

The objects of underdrainage are:

1. To lower the water level in the soil and get it away from the foundations. The action of sun and wind will dry the surface of the road, but if the foundation is soft and spongy the road will soon become a mass of mud.
2. To dry the ground quickly after a freeze. When the frost comes out of the ground in the spring, it thaws quite as much from the bottom as from the top and with proper underdrainage the water, when released by thawing from below, will be immediately carried away.
3. To remove the "underflow." In some places when the ground is comparatively dry when it freezes in the fall, it will be very wet in the spring when the frost comes out. The reason is that after the ground freezes, water rises

slowly in the soil by hydrostatic pressure of the water in higher places; and if it is not drawn off by underdrainage it saturates the subsoil and rises as the frost goes out. The underdrainage not only removes the

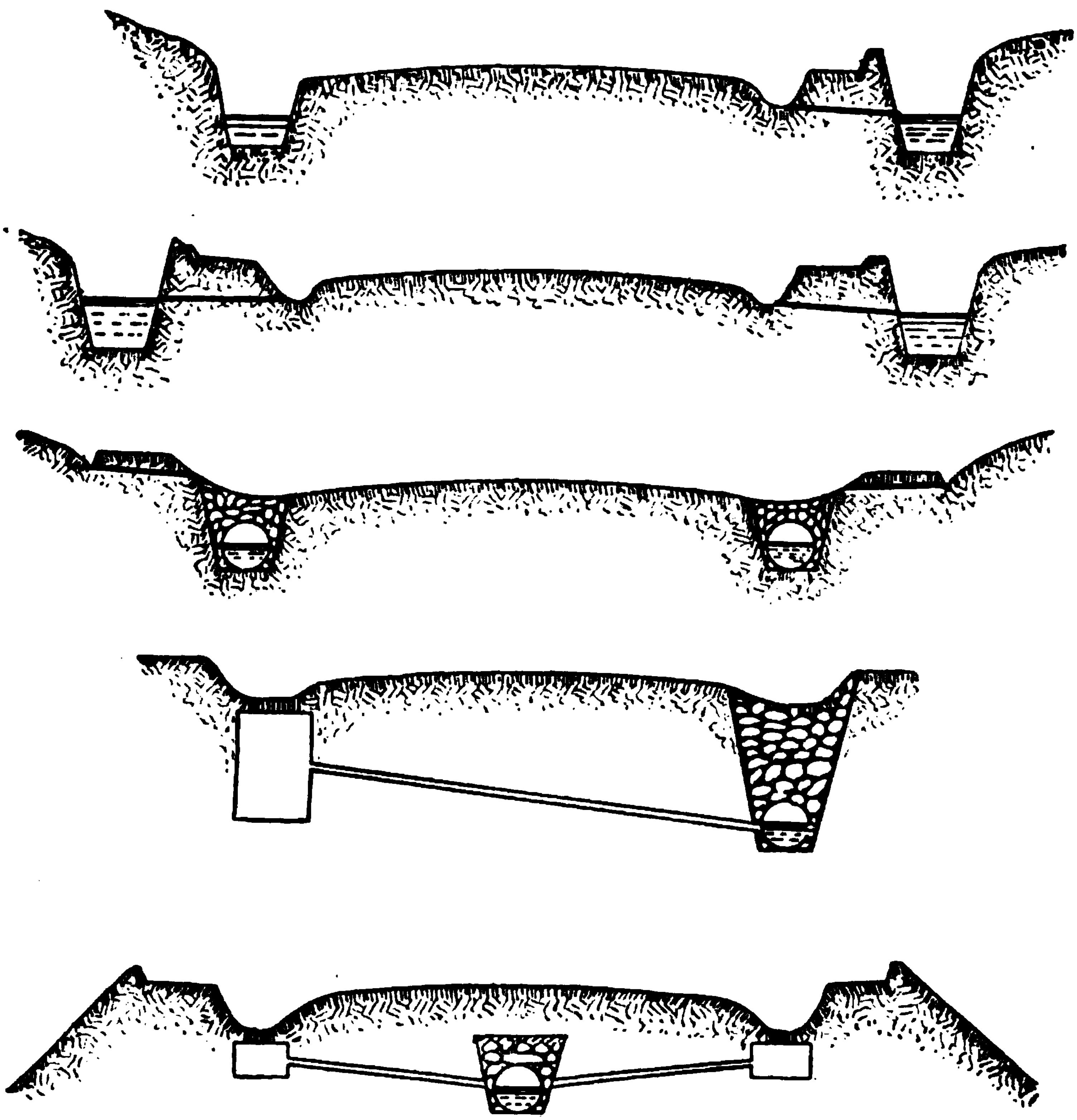


FIG. 28.—Methods of Drainage of Surface Water from Country Roads.
On roads where there are no sidewalks, gutters are formed between the roadway and the pathway, and the water is conducted from these gutters into the side ditches by pipes laid under the walk at intervals.

water, but prevents, or reduces, the destructive effects of frost.

The object of side ditches or gutters is to receive the water from the surface of the traveled roadway, and they should

carry it rapidly and entirely away from the roadside. They also intercept and carry off the water that would otherwise flow from the side hills upon the road. The side ditch need not be deep, and should have a broad flaring side toward the roadway, while the outside bank should be flat enough to prevent caving. It should have a good fall and a free outlet into some stream so as to keep the water moving and to carry it entirely away from the road.

Object of side ditches.

Surface drainage.

Surface drainage of the traveled portion of the road affects mainly the maintenance of the road and is fully as important as the underdrainage. It is provided for by crowning the surface. The slope from the center to the side should be enough to carry the water freely and quickly to the side ditch.

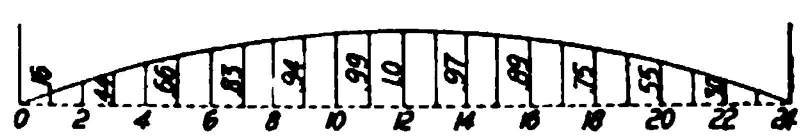


FIG. 29.—Profile of Road Section.

Transverse contour.

There has been much discussion as to the exact crown and slope to be given to the surface of the roadway. Some claim that the shape should be the arc of a circle, others that it should be a parabolic arch started at the curb line or at the edge of the gutter, and still others that it should consist of two planes meeting at the center and having their junction rounded off with a short curve. The last two forms are probably better than the first, but great refinement in this matter is neither possible nor important.

The proper crown varies with the nature of the roadway; when a good surface is maintained a very moderate rise is sufficient, but in all cases this rise should bear a certain proportion to the width of the roadway, as shown approximately in the accompanying table:

TABLE VI

AMOUNT OF TRANSVERSE RISE REQUIRED FOR DIFFERENT PAVEMENTS.

Surface.		Proportion of the width of roadway.
Earth,	Rise at center.	1/40
Gravel,	"	1/50
Broken stone,	"	1/60
Stone Block,	"	1/80
Wood,	"	1/100
Brick,	"	1/80
Asphalt,	"	1/80

Although the curved profile is universally used, no set practice in respect to the crown exists. In some places asphalt

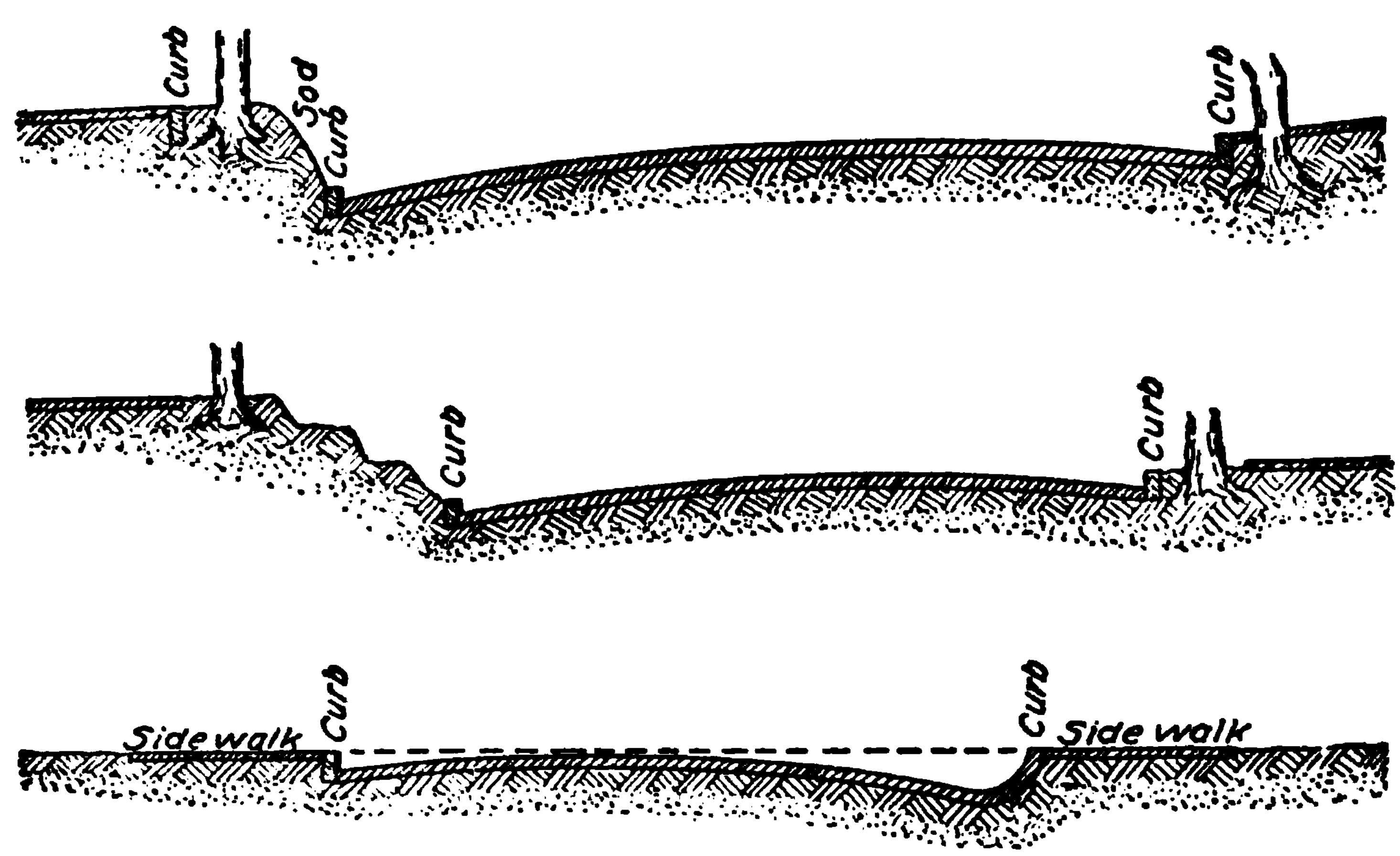


FIG. 30.—Arrangements of Transverse Grade in Cases of Streets in which the Opposite Sides are at Different Levels.

is given the smallest crown of any pavement, while in others, notably in Omaha, it has the largest, both methods seeming to be based on good judgment, the former on the smoothness of the surface and the latter on the fact that asphalt rots when continuously wet.

Highway Bridges

Of the money spent in many parts of the country on the maintenance of a highway system, nearly one-half is expended in the construction and repair of culverts and bridges. Especially in well-watered areas the problem of keeping these works in good repair is one of considerable difficulty. In fact, it is sometimes more necessary to spend money for good bridges than for good roads. Rarely is the condition of a road so bad that it stops travel entirely or becomes actually dangerous to life or property, as happens in case of the destruction of an important bridge.

To secure the safety of a bridge a good foundation for the substructure is of the highest importance; a bridge on a poor foundation cannot be maintained. If the stream bed be too soft to support the substructure, piles should be driven; if it is subject to wash such as to endanger the foundations, special pains should be taken to protect the foundations.

Location.

In building a permanent structure the first thing to be considered is the site upon which it is to be erected, which should, if possible, be in a location where the bridge will be exposed as little as possible to the various influences tending to cause its destruction. It should be so located that the cost of construction will be as low as is consistent with good service to the public, and care should be observed to avoid placing the bridge at a point where a stream is apt to change its bed. For the safety of the public the approaches should be in line with the bridge for as great a distance as possible at each end, especially if the road is on a grade.

By a judicious change in the location of a road, bridges can sometimes be avoided without inconvenience to the public. Fig. 13 (page 50) shows a case in which there are three bridges of 60-feet span over a stream where one would be sufficient for the public convenience.

Highway bridges may be classed according to the materials of which the superstructures are built, as follows:

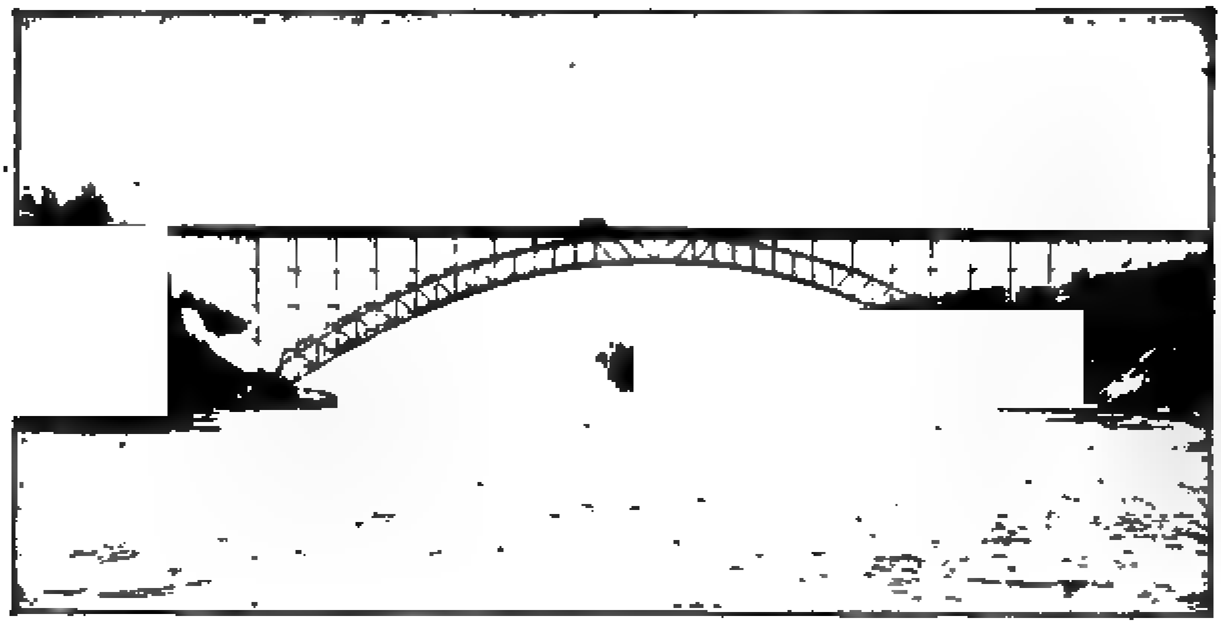


Fig. 31.—Clariton-Clifton Two-hinged Arch Highway Bridge Over Niagara River.

Fig. 32.—Suspension Highway Bridge Over Niagara River.
(From "Design of Highway Bridges," by M. S. Ketchum)

Classification of highway bridges.

1. Steel or iron.
   a. Short span; *b*. High truss; *c*. Plate girder.
2. Steel or iron in combination with timber.
3. Timber.
4. Masonry or concrete.
   a. Arches; *b*. Beam; *c*. Culverts.
5. Reinforced concrete.

There are locations for which each type is adapted. In the past, the cheapness of good lumber, the ease with which tim-

(*From Wis. Geological Survey Bulletin*)
FIG. 33.—The Old Style Highway Bridge.

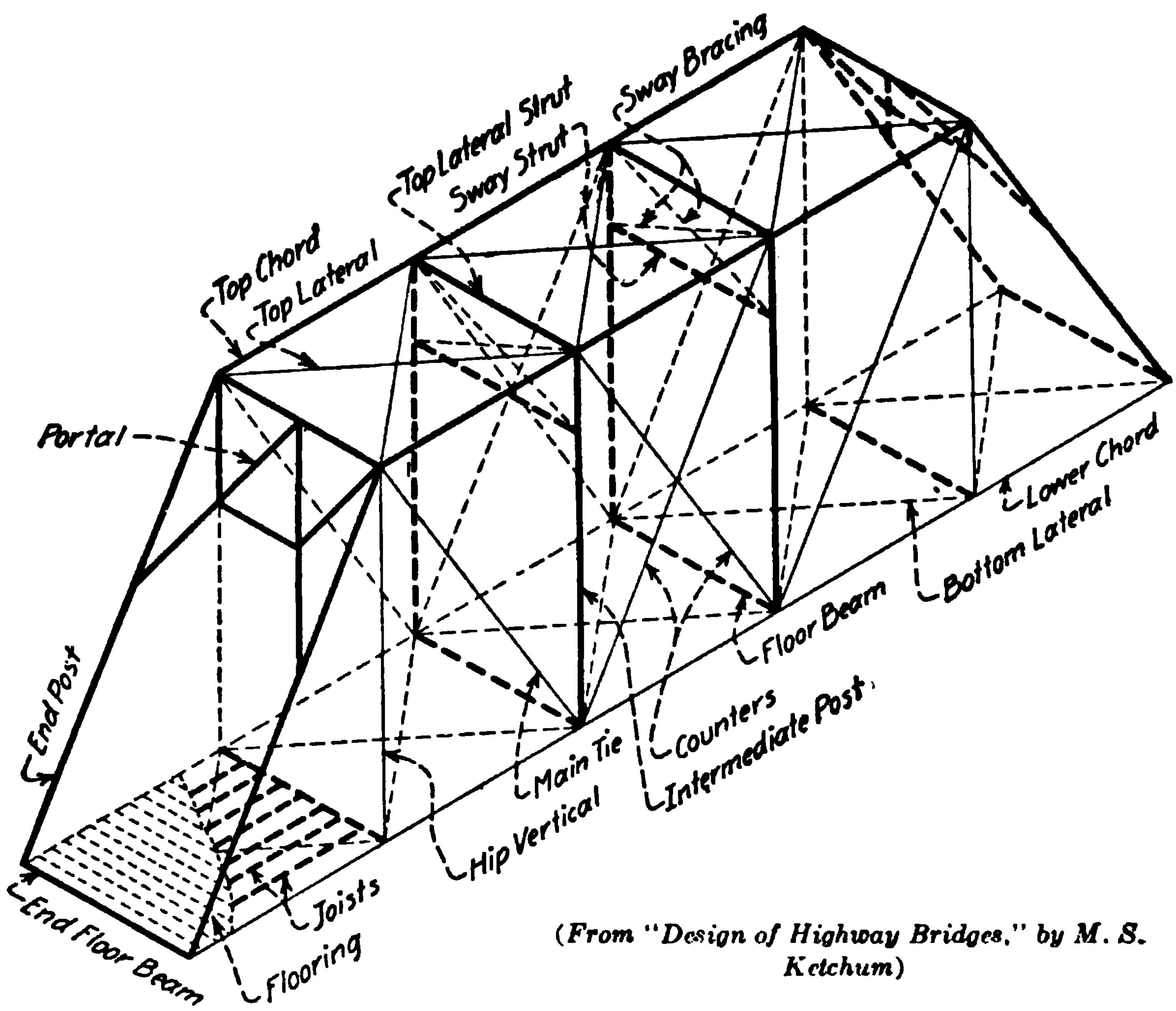
ber bridges could be built and repaired, and the high price of other materials were the causes for the wide use of such a perishable material as timber, but in recent years conditions have changed; lumber has increased in price while the prices of steel and Portland cement have decreased. Steel is the material most widely used and is used for bridges of all spans.

Bridge trusses.

A bridge truss is a framework composed of individual members so fastened together that loads applied at the joints produce only direct tension or compression. In its simplest form every truss is a triangle or a combination of triangles, this being the only geometrical figure

in which the form is changed only by changing the length of the sides. The members of the truss are either fastened together with pins, termed "pin-connected," or with plates and rivets, termed "riveted."

Fig. 34 represents a bridge consisting of two vertical trusses which carry the floor and the load; two horizontal



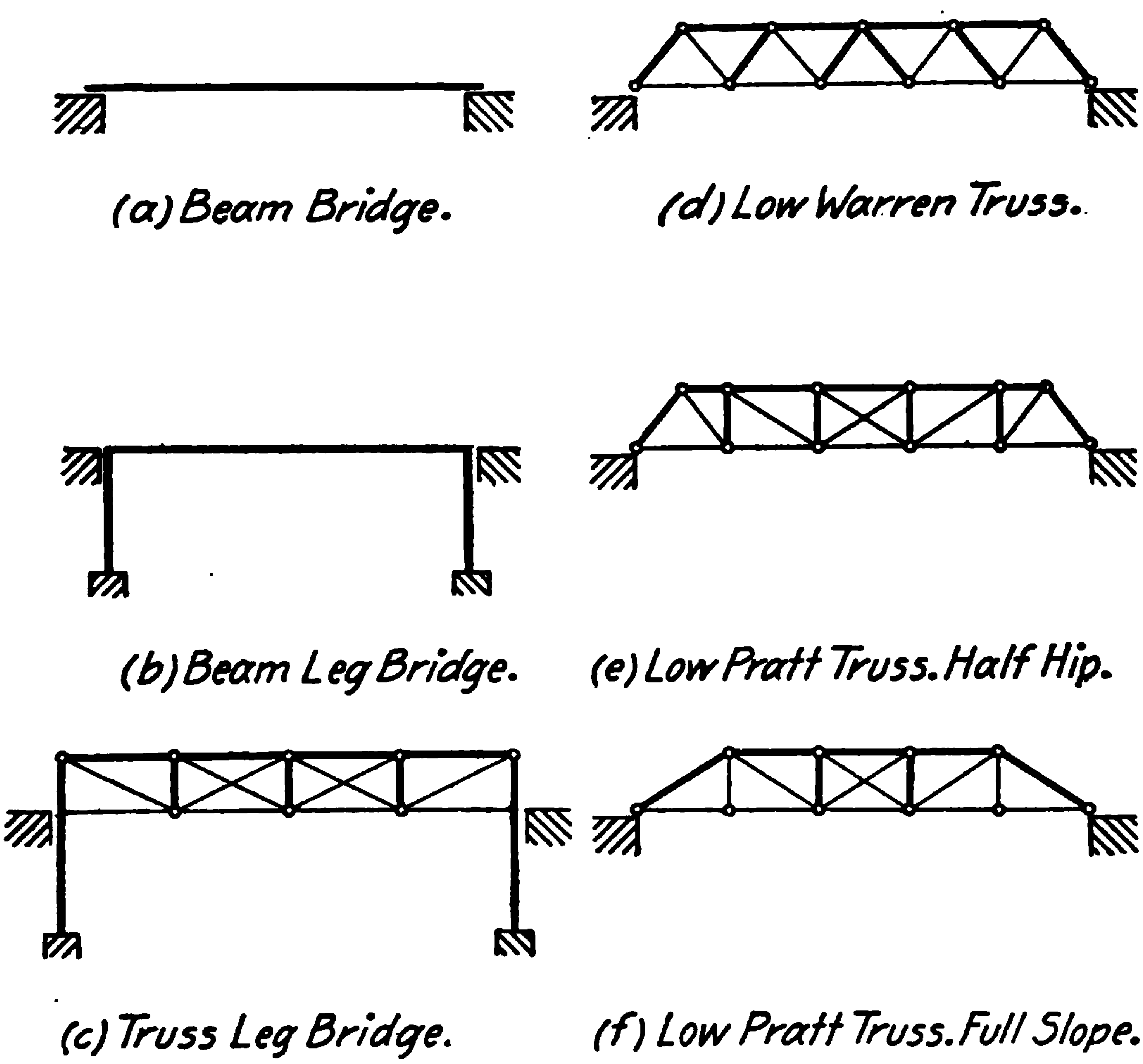
(*From "Design of Highway Bridges," by M. S. Ketchum*)

Fig. 34.—Diagrammatic Sketch of a Through Pratt Truss Highway Bridge.

trusses in the planes of the top and bottom chords, respectively, which carry the horizontal wind load along the bridge; and cross-bracing in the plane of the end-posts, called "portals," and in the plane of the intermediate posts, called "sway bracing." The floor is carried on joists placed parallel to the length of the bridge, and which are supported in turn by the floorbeams. The main ties, hip verticals, counters and intermediate posts are together called "webs." The bridge shown

in Fig. 34 is a "through pin-connected" bridge of the "Pratt" type, the traffic passing through the bridge. Short-span highway bridges have low trusses and no top lateral system or portals.

The simplest type of bridge is the "beam" bridge (*a*) Fig.



(*From "Design of Highway Bridges," by M. S. Ketchum*)

FIG. 35.—Types of Short Span Highway Bridges.

35. This commonly consists of I-beams which span the opening, and are placed near enough together to carry the floor of the bridge. Where foundations are relatively expensive the beams may be carried on posts as in (*b*). A "Truss Leg" bridge is shown in (*c*). A "Warren" truss is a combination of isosceles triangles as shown in (*d*). The "Pratt" truss has its vertical web members in compression while its diagonal web members

Types of trusses and bridges.

are in tension, as shown in (*e*) and (*f*). The "Warren" truss is commonly built with riveted joints while the "Pratt" truss is usually built with pin-connected joints. The "Warren"

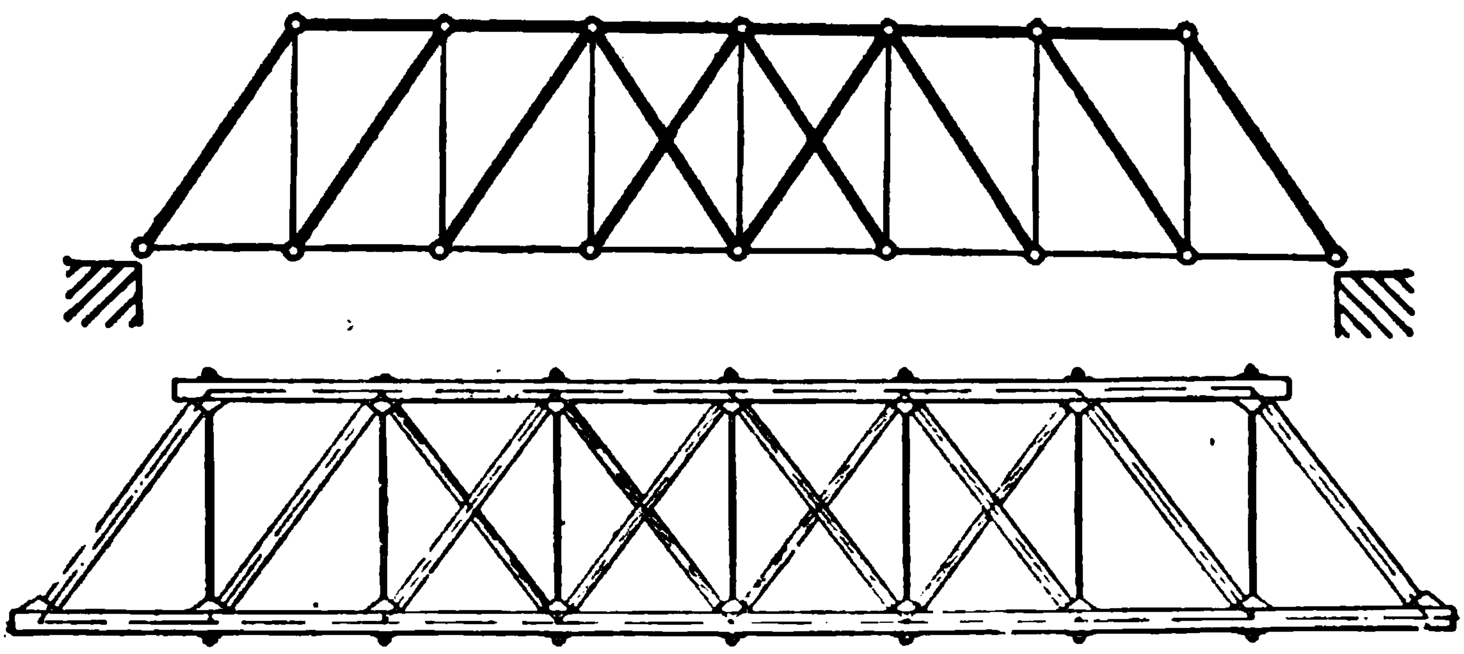


Fig. 36.—Through Howe Truss.

low truss with riveted joints as shown in (*d*) is generally preferable to the low "Pratt" truss in either (*e*) or (*f*).

The "Howe" truss has its vertical web members in tension,

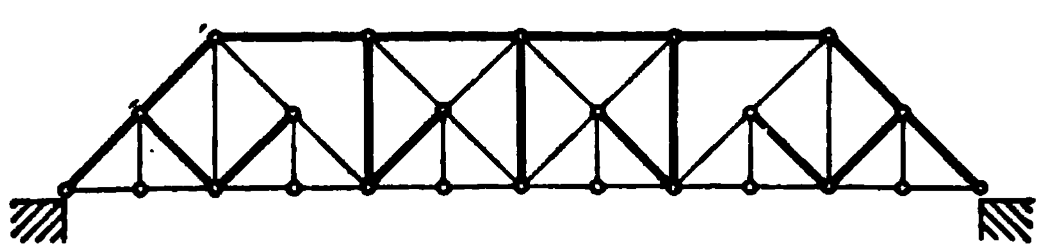


Fig. 37.—Baltimore Truss.

and its inclined web members in compression, as in Fig. 36. The upper and lower chords and the inclined members of a "Howe" truss are commonly made of timber, while the vertical tension members are iron or steel rods.

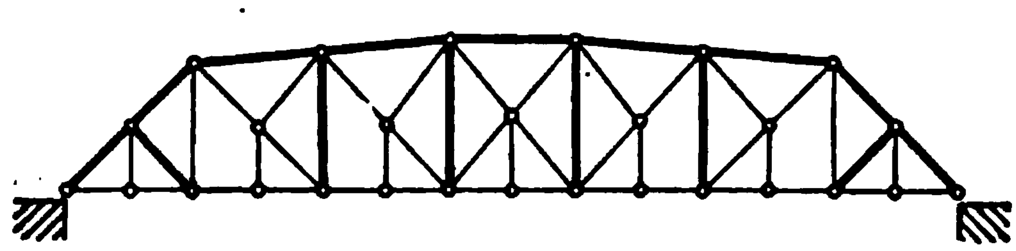


Fig. 38.—Petit Truss.

The "Whipple" truss is a double intersection "Pratt" truss. This was designed to give short panels in long spans which have a considerable depth.

The "Baltimore" truss is a "Pratt" truss with parallel chords in which the main panels have been subdivided by an auxiliary framework as in Fig. 37. The "Baltimore" truss with inclined upper chords, is called a "Petit" truss.

FIG. 39.—Typical Leg Bridge.

Short span highway bridges include beam, leg and low-truss bridges.

Beam bridges are made by placing steel beams side by side

FIG. 40. (*a*) and (*b*).—Illustrating Deflection of Supports of Leg Bridge.

Fig. 40 (*a*). *a* shows the position of the top of the upright leg at time of erection with fall of temperature, the floor joists shorten and the legs assume the new position *b*; With increase in temperature the tops of the legs are forced back towards their original positions, and the bank is compelled to yield to their pressure, but mainly at the top. The legs will then assume the curved position *c* in Fig. 40 (*b*). The tendency of the curved beam to straighten throws the foot out and the leg takes a step into the stream the final position being shown at *d*. This process is repeated with every recurring change of temperature.

with the ends resting in the abutments. The roadway floor is usually made of planks laid transversely on top of the beams. The spacing of the beams depends on the load to be carried and upon the thickness of the floor planks, for which a common rule is that the plank

Short-span bridges.

Fig. 41.—A Warren Low Truss Highway Bridge.

Fig. 42.—A Pratt Low Truss Highway Bridge; Seven 100-ft. Spans.

shall have at least one inch in thickness for each foot of spacing of the joists or stringers. The outside beams carry a smaller load than the intermediate beams and are usually steel channels, while the intermediate beams are steel I-beams having a depth of about $\frac{1}{30}$ of the span.

Beam and truss bridges are sometimes supported on steel legs in the place of abutments, and should be designed to carry the thrust of the filling in addition to the live and dead load on one-half of the span. Unless very carefully designed and constructed, leg bridges are inferior structures and are not to be recommended.

Fig. 43.—A Pratt Low Truss Bridge 40-ft. Span with Concrete Floor.

Low-truss bridges.

Low-truss bridges are used for spans of from 30 to 80 feet, and special designs to about 100 feet. The trusses may have either pin-connected or riveted joints; they may have either half-hips, or full slopes, and may be either of the "Warren" or the "Pratt" type.

High-truss bridges.

High-truss bridges with spans of from 80 to 170 feet are built with parallel chords and with either pin-connected or riveted joints; with spans of from 160 to 220 feet, they are usually built of the "Pratt" type with inclined upper chords trusses; with spans above 220 feet, bridges are usually built with the "Petit" type of

Fig. 44.—Cantilever Highway Bridge.

Fig. 45.—Plate Girder Highway Bridge.
(From "Design of Highway Bridges," by M. S. Ketchum.)

truss. High-truss pin-connected bridges should never be built with less than five panels.

Plate-girder bridges.

A "plate girder" consists of a vertical steel or iron web plate to whose top and bottom edges are riveted horizontal pairs of angles to form flanges, and to whose ends are attached vertical angles which transmit the load to the supports.

A plate-girder highway bridge consists of two or more, usually two, plate girders fastened together by lateral bracing. The roadway is carried on a floor system supported near the bottoms of the plate girders. Short spans up to 70 or 80 feet have one end fixed while the other end is allowed to move on a sliding plate. For greater lengths of span the expansion end is supported on nests of rollers. The ordinary limit of plate-girder spans is about 100 feet.

Use of timber in bridges.

Timber was formerly quite generally used in the construction of highway bridges, and is still used for temporary structures in locations where timber is cheap and iron and steel are relatively expensive. It is used in (1) timber trestles, (2) timber bridges and (3) combination bridges, in which the top chords and intermediate parts are made of timber while the tension members are made or iron or steel.

Wooden bridges are expensive to maintain, and, where built strong enough to carry heavy loads their first cost is high. They are dangerous, since they will often give way without showing any signs of weakness.

Masonry and concrete bridges.

When properly constructed, masonry and concrete bridges are permanent, and this type of structure should be given the preference when conditions are favorable for its construction.

Stone arches have been built from time immemorial, and while many existing arches are standing after hundreds of years it is equally certain that many have fallen down. Rightly built they are permanent, since there is nothing to decay, and to break them down it is necessary to crush the rock of which they are built.

Reinforced concrete beam bridges for short spans up to 15

Fig. 46.—Reinforced Concrete Bridge, 20-ft. Span.

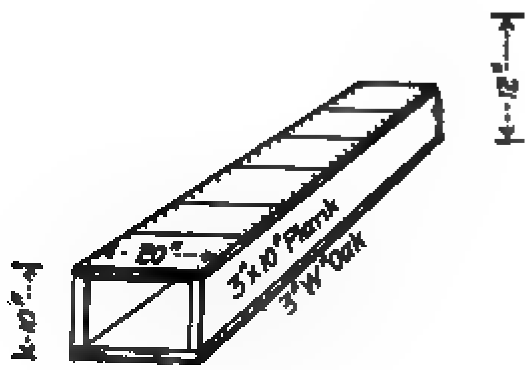


Fig. 47.—Timber Box Culvert.

Fig. 48.—Timber Culvert.

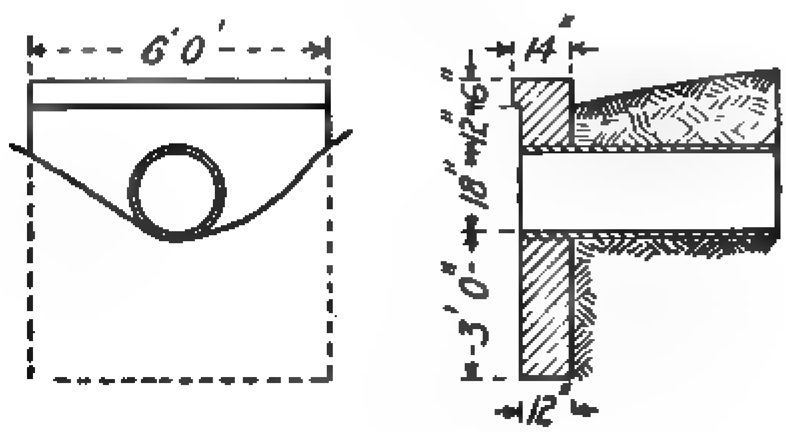


Fig. 49.—Endwalls for Pipe Culverts.

to 20 feet are commonly made of a single slab of uniform thickness spanning the opening. For longer spans the floor system is made of deeper horizontal girders supporting a relatively thin floor slab.

FIG. 50.—A Well Built Concrete Culvert.

FIG. 51.—A concrete culvert cracked a few days after being built, due to the concrete not being thoroughly mixed and tamped.

Culverts.

Culverts are made of timber, vitrified clay brick, cast iron pipe, brick, stone, concrete, and reinforced concrete. For temporary culverts the timber box may be used, the bottom being paved to prevent scour. Care should be used to tamp the filling to prevent water flowing

along the sides. Timber culverts are very unsatisfactory and in the long run are very expensive. Pipe culverts should be laid on a firm foundation and to a careful grade. The center should be raised so that there will be no hollows in the pipe. Head walls, preferably of masonry or concrete, should extend high enough to carry the fill, and should be carried down far enough to prevent the water from following along the outside of the pipe, which should preferably be laid in concrete.

The location of culverts should also have careful consideration; often they are built and maintained where they are unnecessary. It is of no benefit to carry water across a road in a culvert unless it can be carried away from the road at that point; it should be carried along a road as long as its volume does not become so great as to cause serious washing. Culverts should, of course, be built with a view to permanency, and they should be protected.

Size of opening.

An important feature in the planning of a bridge or culvert is the making of a careful estimate of the amount of water for the passage of which it is necessary to provide. This is always done by railroad companies in planning their structures and should be done for every highway structure as well.

The amount of water that will come from a certain drainage area and flow through any culvert or under any bridge in a given amount of time can be determined only in a general way and rarely with any high degree of accuracy, as it depends upon too many factors. These are:

1. Area of drainage basin.
2. Maximum rainfall per hour.
3. Slope of the surface.
4. Character of the soil—porous or compact.

Some of the more important of these factors are practically unknown, as even the most carefully kept weather records seldom give the rainfall for each shower, which is the point of importance in determining the amount of water to be provided for. The amount of water which the soil will absorb may vary from a small percentage to almost the whole amount of the

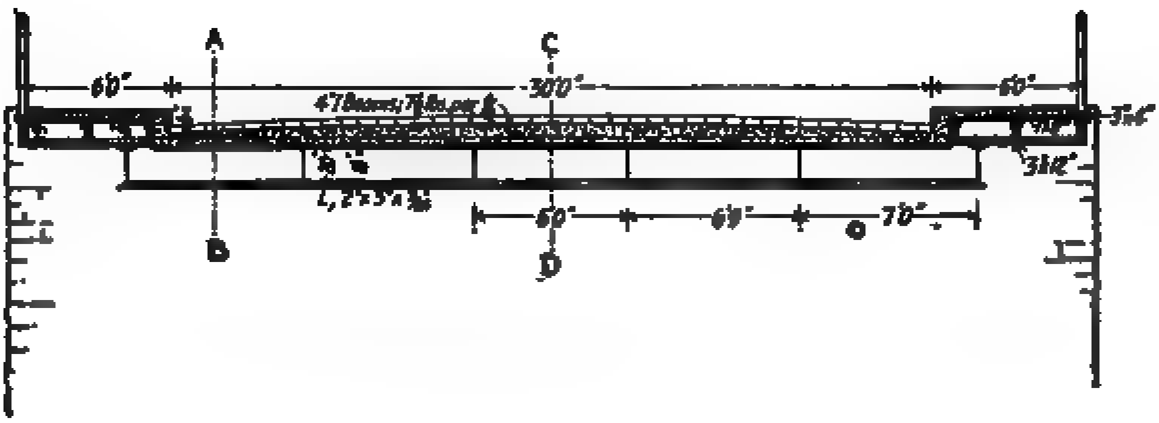
rainfall, depending on its conditions at the time of the shower.

Floorbeams and floors. Floorbeams for highway bridges are made of rolled I-beams or riveted plate girders, and may be riveted to the posts or hung from the lower chord pins. Joists or stringers are made either of rolled I-beams or of timber. The floors are made of timber, reinforced concrete, bent steel or iron plates or bars, or angles and plates filled with concrete.

In the past steel bridges have generally been built with plank floors, but the increase in the price of lumber has resulted in the use of the more substantial materials which will endure as long as the bridge.

Substructures. In any type of bridge it is of the utmost importance that the superstructure be well supported. If this is not done the best bridge that can be constructed will fail. When an arch fails it is generally because the foundation has settled. In the case of steel structures, failures are often the result of failures in the substructure. These bridges are designed to withstand certain forces applied in certain ways. So long as the bridge rests securely upon the substructure, the conditions expected in the design are fulfilled, but if the structure settles to any great extent, strains which are entirely unexpected and consequently not provided for in the design are introduced, and though the bridge may not fail all at once its joints become loose, the trusses get out of line, the bars begin to rattle badly when any considerable load crosses, and the structure weakens much more rapidly than under ordinary conditions. The forms of substructures ordinarily employed are abutments and piers of stone or concrete, and steel piling.

Abutments. An abutment is a structure, commonly made of masonry, that supports the ends of the bridge and acts as a retaining wall to hold back the earth fill. A pier is a structure that supports the ends of the bridge where there is no filling to support. Abutments and piers are generally at right angles with the center line of the bridge. A bridge in which the abutments are not at right angles to the center line is called a "skew" bridge.



Transverse Section.

FIG. 52.—Beam Bridge with Solid Floor.

FIG. 53.—Details of Concrete Floor.

FIG. 54.—A Substructure of Five Light I-beams with a Backing or "Abutment" of Planks which will have to be Renewed Every Few Years.

(*From "Design of Highway Bridges," by M. S. Ketchum*)

FIG. 55.—Concrete Abutments for 111′ 6″ Span Steel Riveted Highway Bridge Across Illinois and Mississippi Canal.

Abutments are made with

1. A straight main section without wings.
2. Wings making an angle of from 30 to 45° with the axis of the stream.
3. A T-section, the stem of the T running back into the fill.
4. A U-section where the wings make an angle of 90° with the axis of the stream.

Highway bridge abutments are usually made with wing walls, the wings making an angle of 30 to 45° with the face of the abutment. The abutment with wing walls holds the filling and gives a freer channel than any of the other types.

(From Wis. Geological Survey Bulletin)
FIG. 56.—The Result of Flimsy Construction.

While abutments of stone or concrete are practically unaffected by decay they may be destroyed by undermining. The foundation should always be at such a depth that there will be no danger of wash, and if in soft ground, piles should be driven. One great advantage of stone or concrete abutments over all other structures is that they serve as retaining walls and permit embankments to be made right up to the end of the bridge. When built with suitable wing walls the embankments are well protected against washing.

The most economic bridge is the one which in the long run will give the best service and cost the least money, taking as a measure of the cost the amount of money which it will be necessary to capitalize in order that the interest may pay for (1) the maintenance and repairs, (2) the interest on the first cost, and (3) a sinking fund for depreciation so that the bridge may be replaced when it is no longer fit for the service demanded.

Most economic bridge.

The possible life of any particular bridge is difficult to estimate. Steel bridges, if properly constructed, should last from 25 to 40 years; combination bridges, from 10 to 15 years, while masonry and reinforced concrete bridges are ordinarily considered as permanent structures. Timber floors must be replaced in 3 to 5 years, and steel bridges should be painted every 3 to 4 years. Hence the first cost of a bridge is not a safe criterion upon which to base economy. Much money is wasted in putting in cheap, flimsy, bridges which are short-lived, unsatisfactory and are continually in need of repairs.

Retaining Walls

A retaining wall is a structure that retains the lateral pressure of the earth on hillsides. The pressure of the material supported varies considerably, depending upon the material, the manner of depositing it in place, and upon the amount of moisture. If dry clay is loosely deposited behind the wall it will exert the full pressure due to this condition. In time the earth becomes consolidated and cohesion and moisture make a solid clay, which often causes the bank to shrink away from the wall, and there will be no pressure exerted. On the other hand, if a considerable amount of water is added, the normal pressure rapidly increases and approaches that due to a liquid having the same specific gravity.

Retaining walls should be built on steep hillsides and mountain roads—

Where retaining walls are built.

1. At all re-entering curves.
2. At all culverts and bridges.
3. On the edge of all precipitous places.
4. When the bank slope and the ground slope are nearly or quite parallel to each other.

5. Where a bank would be of excessive length owing to the angle of the natural ground slope.
6. Where a wall would be cheaper than a bank.

On the edges of dangerous precipices, when there is a heavy

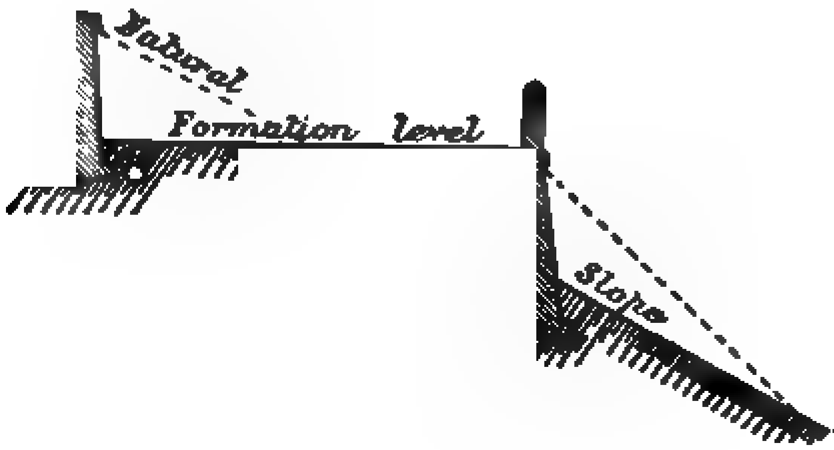


FIG. 57.—Road Construction on Hillside, with Retaining Walls.

FIG. 58.—Surcharged Wall.

A wall is said to be "surcharged" when the bank it retains slopes backwards to a higher level than top of the wall.

load to support, the walls should be built of masonry, but where the pressure is not too great they may be built of large stones laid dry. They should be carried up as high as the natural surface of the ground or to the surface of the roadway

and a parapet wall or fence raised upon it, to protect pedestrians against accident.

Dry stone retaining walls are best suited for roads on account of their self-draining properties and their cheapness.

Drainage.

The filling back of the wall should be entirely of stone if it is available. Where earth is used it should be deposited and tamped in approximately horizontal layers or in layers sloping back from the wall, and a layer of sand, gravel, or other porous material should be deposited between the fill and the wall to drain the fill downwards. In case of masonry retaining walls, to insure drainage of the filling, drains should be provided back of the footing and "weep-holes" should be provided in the body of the wall

a. Stepped Profile. *b.* Ogee Profile. *c.* Vertical Profile.

FIG. 59 —Sea Walls.

at frequent intervals to allow the water to pass through. The filling in front of the wall should also be carefully drained.

Sea walls.

Roads along the seashore are protected by sea walls, which resist the wave action and support the embanked roadways. The principal weakness of most sea structures, especially those directly opposed to the action of the waves, lies in the liability of the foundation to wash out. To provide against this the footings should be carried well down, and the profile of the wall should be such as to break up the waves with the minimum effect on the foundations.

The stepped profile is believed to accomplish this object better than any other form, as the steps break up the waves,

and reduce the volume of water likely to be thrown on to the roadway. The ogee profile looks well but is less effective in breaking up the waves, is more troublesome to construct, and is not as strong as the other forms. The vertical, or nearly vertical, profile is used in locations open to really heavy seas.

CHAPTER VI

MATERIALS USED IN ROAD CONSTRUCTION

A GREAT variety of material enters into the construction of present-day roads on account of the widely varying climatic, geologic and topographic conditions which exist in this country as a whole and almost equally so of any particular state or locality. Materials which might be used with economy in one locality may be entirely unserviceable elsewhere because of excessive cost of haulage. This forms so large a part of the cost that an inferior material may often be useful economically on account of the expense of securing a superior material. In general it may be stated that for country roads, materials from local sources must be employed.

Most suitable material.

The best material available should be chosen, and if not very strong, it will suffice where the traffic is moderate, a greater quantity making up for want of durability, but more labor will be required to keep the surface of the road in proper order than with a better material. With heavier traffic the use of a better material, even at a higher price, becomes more advantageous, and in or near large towns the best material at almost any price is generally the most economical in the end. This is especially the case when the dirt arising from wear must not only be scraped off constantly, but be removed altogether from the road. Sometimes a stronger and more costly material may be used for the surface only, the body of the road being made of inferior local stone. For repairs, the better material may be laid only on the middle of the road, where the wear is the greatest.

In the making of new roads, and to a greater extent in the selection of the most suitable spots for opening the necessary quarries for supplying road-making materials, geology, chem-

istry, and petrology all contribute to the knowledge necessary for the proper scientific study of the materials. While observation of the behavior of the stones in a road may be more convincing than theoretical knowledge, time is necessary for such a trial, and the material may, after all, turn out to be deficient in durability. Experience has shown that even in the same quarry, remarkable differences exist in the quality of the rock which, to all appearance, is of a similar nature, and it is only by a microscopical examination of the rock that these peculiarities and the diverse wearing properties of different rock-types can be detected. To the science of petrology, therefore, must the road engineer look for that assurance, which, combined with a study of the physical tests and his own knowledge of the actual use of some reliable types of road-stone, will insure the most suitable and durable material being selected for any particular road.

The materials most commonly used for roads and pavements are:

1. Stone, in the form of blocks and broken fragments.
2. Wood, in the form of blocks and planks.
3. Asphalt in two forms: sheet and block.
4. Concrete.
5. Sand.
6. Clay.
7. Gravel.
8. Bituminous materials (other than sheet and block asphalt).

Selection of material. In order to determine the fitness of the different materials under any given conditions of service, it is necessary to know:

1. The agencies causing their destruction.
2. The extent and character of the traffic.
3. The topographic and climatic conditions under which they are to be used.
4. The properties which the materials must possess in order to resist the destroying agencies.
5. The most reliable method of ascertaining experimentally the extent to which the materials possess the required properties.

Other things being equal, the endurance of a roadbed

depends upon the qualities of the materials used, assuming the road to be properly constructed and adequately drained. A road is subject to attack and consequent loss of material in part by reason of the composition of that material. The other forces operating upon the surface to destroy the road or pavement are: (1) physical, (2) mechanical or dynamical, (3) chemical, (4) organic. It is estimated that the mechanical agencies cause 80 per cent of the destruction and the others 20 per cent.

Agencies causing destruction of roads.

The physical agencies are:

Physical agencies.

1. The disrupting effects of frost and ice, both on the integrity of the road bed as a whole and on the individual rock fragments and minerals.
2. The transporting power of water.
3. The transporting power of the winds.
4. Heat due to changes of temperature.
5. The attrition and effect of falling rain.
6. Gravity.

It has been the object of the highway engineer ever since the days of Macadam to construct a road in such a manner that frost action above subgrade may be reduced to a minimum. Macadam contended strenuously for a dry foundation. The evils resulting from the disrupting effects of water alternately freezing and thawing in the foundation of a road are apparent and are well known. Freezing action not only disrupts a road as a whole, but its presence in stones is promotive of weakness and more rapid crumbling. The presence of frost in fragments of broken stone operates to increase their brittleness to a considerable degree, and for this reason gives rise to a more rapid disintegration of the screenings and the upper portion of the road. In the formation of ice, 100 volumes of water expands to 109 volumes of ice, and the pressure exerted on cooling the water one degree below the normal freezing-point is 144 tons per square foot. Its most destructive effect, therefore, is produced in the structure of the pavement and its foundation; if the construction is defective and the maintenance poor, water accumulates in the body of the roadway,

and on freezing either destroys the bond or weakens it materially.

The ability of water as a medium of transportation of material depends upon the specific gravity, the size and the form of the fragments, and upon the velocity of the water, or, what amounts to the same thing, the grade of the roadbed. The gullying of roadbeds during heavy rains or melting snows by washing particles of sand and clay to the side drains and ditches is the most conspicuous work done by flowing water, but the sorting process it exercises even on gentle slopes, where the grains of the least weight and specific gravity are forced to the surface of the road to be blown away by the wind, is also important. This sorting action arises from the fact that the sand grains will arrange themselves in water in the order of their specific gravities, the heaviest at the bottom.

The combined operation of wind and water play a considerable part in the destruction of the roadway. Measurements made by French engineers show that about seven cubic yards of material per mile per annum are removed by these agencies. Considered from the point of view of wind action alone, the ability of wind to carry away grains of any rock depends on:

1. The form of the particles subjected to the wind's influence.
2. The specific gravity and size of the individual grains.
3. The accessibility of the grains to the action of the wind.

Heat, through changes of temperature, causes expansions and contractions which produce a slight movement among the component particles of the material, thus breaking their cohesion and leaving them more susceptible to the destroying effect of the other agents.

The impact of falling rainwater, while relatively unimportant as a source of injury, causes a certain amount of attrition and loosening of those grains which it is able to move about, and a certain breaking of the coherency of the surface as far down as the water is able to penetrate.

Gravity also plays its part, as seen by the work done in running water and falling rain, but through its operation alone

there is always a tendency for grains and fragments of rock to work down the slopes towards the sides of the road, which may in time completely destroy a roadbed.

The mechanical, or dynamical, agencies are:

Mechanical agencies.

1. Friction, resulting from the grinding action of one fragment of rock against another, due to traffic, as,

   a. Impact produced by the action of horses' feet.

   b. Percussive and abrading action of moving wheels.

   c. Crushing due to the weight of the load on the wheels.

2. The disrupting effect of roots.

The gradual destruction of a roadbed by the ordinary processes of friction and impact is always to be expected, and if these forces are applied in the presence of water, thus producing attrition in the presence of a solvent, their destroying effects are most energetic.

The chemical agencies are:

Chemical agencies.

1. Decomposition, shown, for example, by the disintegration of the feldspar-bearing rocks whereby the feldspars and other minerals are converted into clay, quartz, calcite, etc.

2. Solution, or the power possessed by surface waters impregnated with acids to dissolve most rocks and to carry them away.

The action of the chemical agencies is very slow, and their effect may be ignored except in the case of rocks already in a state of decomposition or containing readily soluble mineral matter. The rocks that are most susceptible to the solvent action of water impregnated with acids are the limestones, calcareous sandstones, and the granites containing feldspar.

The softening or partial decomposition of a road-stone by these chemical changes has generally been regarded as a destructive element in road maintenance, but although it appears from recent investigations, that the chemical decomposition is not so destructive as it was formerly imagined to be, it can hardly be doubted that the weathering properties of a stone are determined by resistance to chemical action. And although this may be, in some instances, slow and not

appreciable on the surface of a road which is renewed from time to time, the internal structure, by the solvent action of surface waters percolating through the coating under abnormal conditions of weather, must be adversely affected.

Organic agencies. The organic agencies are vegetable or fungus growths that thrive in damp, shady places.

The essential qualities of a good roadmaking stone may be stated as follows:

Paving Blocks: Hardness, toughness, durability, uniformity of wear, retention of a rough surface under traffic in all conditions of weather.

Essential qualities of roadmaking stone. *Macadam:* Hardness, toughness, durability, retention of rough surface (though this does not apply to the extent as in paving blocks), and the property of binding necessary to maintain cohesion under varying conditions.

These qualifications are rarely found together in any high degree. Thus flint, though hard, is often brittle, and some schistose or slaty rocks, although hard and tough when quarried, often disintegrate when exposed to the weather. The quality of cohesion is rarely found in combination with extreme hardness and toughness. Material well consolidated and united in a mass, resists crushing much better than when loose, and good binding property enables a stone comparatively weak to wear better than a harder stone which does not bind.

Hardness. Hardness is an essential quality and may be described as that resisting property which a solid offers against any displacement of its parts or abrasion of its surface. The definition adopted by the U. S. Road Material Laboratory is "the resistance which a material offers to the displacement of its particles by friction." When applied to materials used for paving it signifies the resistance offered by the material to wear by abrasion under the action of wheels.

Hardness varies inversely as the loss in weight by grinding with a standard abrasive agent. A test piece in the form of a cylinder about three inches in length by one inch in diameter is placed in the grinding machine in such a manner that the base of the cylinder rests on the upper surface of a circular

grinding disk of cast iron, which is rotated in a horizontal plane by a crank movement. The specimen is weighted so as to exert a pressure of 250 grams per square centimeter against the disk, which is fed from a funnel with sand of about 1½ mm. in diameter. After 1000 revolutions the loss in weight of the sample is determined and the coefficient of wear obtained by deducting one-third of this loss from 20.

Toughness is also essential quality, and is that property

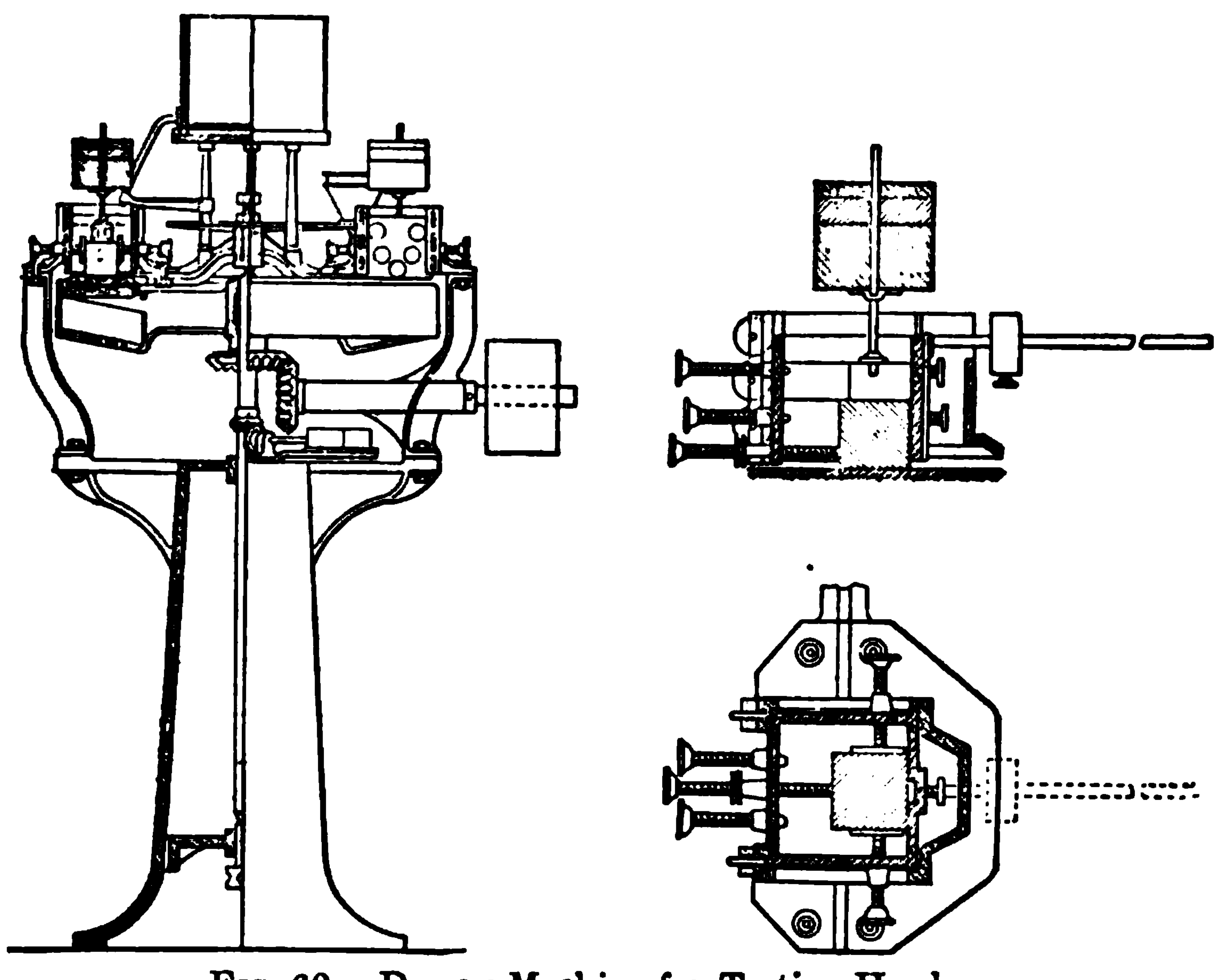


FIG. 60.—Dorrey Machine for Testing Hardness.

Toughness. which admits of the constituent minerals yielding to a small extent without separation of the parts, and enabling the stone to resist fracture by impact. As applied to a paving material it may be defined as that property which enables it to resist fracture under the blows and concussions produced by traffic. The determination of toughness is obtained by the use of a test piece similar to that used in determining hardness, and the test is made with an impact machine constructed on the principle of a pile driver. The

Fig. 61.—Page Machine for Determining Toughness.

Fig. 62.—Page Impact Machine.

blow is delivered by a hammer weighing 2 kg., falling 1 cm. for the first blow, which is increased by 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to cause this failure represents the toughness.

Durability.

Durability depends on the hardness and cohesion of the material, and also on the chemical stability of the constituent minerals. Not only is the tendency to decompose present in most stones when brought under the oxidizing influence of air and water, but nearly all paving and road materials are further subjected to the solvent action of impure surface water, hence the question of the resistance of a road material to chemical agents is, as might be supposed, of great importance.

Percentage of wear, representing durability, is the amount of material under 0.16 cm. in diameter lost by abrasion from a

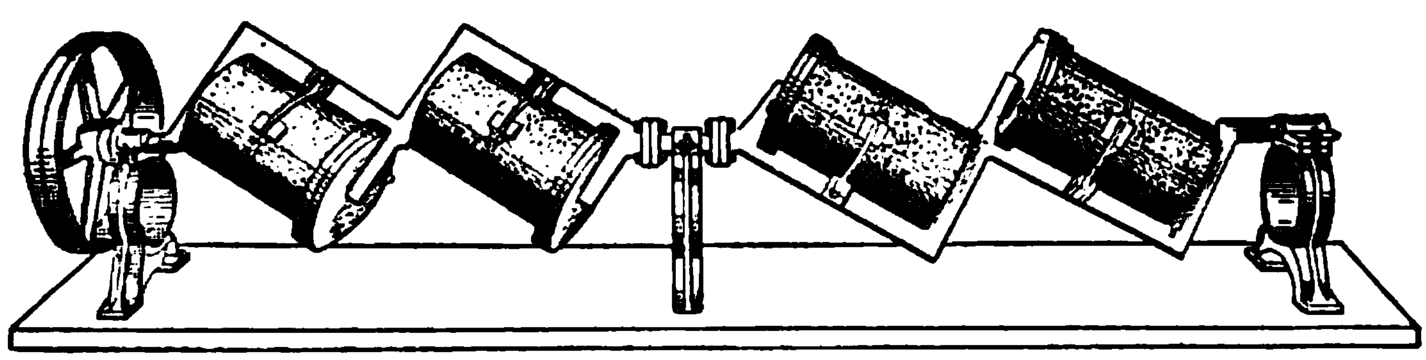


FIG. 63.—Deval Machine for Testing Resistance to Abrasion and Impact.

weighed quantity of rock fragments of definite size. The rock sample is broken into pieces that will pass through a 2.4-inch ring but not through a 1.2-inch ring, and after being thoroughly cleansed, dried, and cooled, 5 kg. are weighed and placed in a cast iron cylinder (34 cm. deep by 20 cm. in diameter) closed at one end and having a tight-fitting iron cover at the other. This cylinder is one of four attached to a shaft so that the axis of each is inclined at an angle of 30° with that of the shaft. These cylinders are revolved for five hours at the rate of 2000 revolutions per hour, during which the stone fragments are thrown from one end of the cylinder to the other twice in each revolution. At the end of five hours the

machine is stopped, the cylinders opened, and their contents poured into a basin, in which every stone is carefully washed to remove any adherent detritus. This abraded material is then thoroughly dried, and from the amount lost below 0.16 cm. the per cent of wear is estimated.

Cementing value.

The cementing value, or binding power, of a road material, is the property possessed by a rock dust to act as a cement on the coarser fragments comprising crushed stone or gravel roads. This property is a very important one and is determined approximately as follows: One kg. of the rock to be tested is broken sufficiently small to

FIG. 64.—Briquette Machine.

pass through a 6 mm. but not a 1 mm. screen. It is then moistened with a sufficient amount of water and placed in an iron ball mill containing two chilled iron balls weighing 25 pounds each and revolved at the rate of 2000 revolutions per hour for two hours and a half, or until all the material has been reduced to a thick dough, the particles of which are not above 0.25 mm. in diameter. About 25 grams of this dough is then placed in a cylindrical metal die, 25 mm. in diameter, and by means of a specially designed hydraulic press, known as a briquette machine, is subjected to momentary pressure of

100 kg. per square centimeter. Five of the resultant briquettes, measuring exactly 25 mm. in height, are taken out and allowed to dry for 12 hours in air and 12 hours in a hot oven at 100° C. After cooling in a desiccator they are tested by impact in a machine especially constructed for the purpose. The standard fall of the hammer for a test is 1 cm., and the average number of blows required to destroy the bond of cementation in the five briquettes determines the cementing value.

The rocks from which stone for paving purposes is obtained vary in quality within wide limits, according to their geological position, physical structure, and chemical composition. Several varieties of structure are met with the same chemical constituents, this being due to the degree of crystallization of the mineral elements. These differences fit the various rocks for special purposes.

Classification of rocks.

The choice of suitable words to describe the different stones which are used in road-building is not an easy matter. When petrological terms are used they are often applied incorrectly, one of the difficulties of this way of naming stones being due to the fact that the different minerals forming the important constituents of these stones are combined in such varying proportions that the different kinds of stone shade into one another, and many may properly be called by any one of several names.

A systematic arrangement of rocks (Table VII) has been adopted by the Office of Public Roads of the U. S. Department of Agriculture. This has been made more from the standpoint of the road-builder and engineer than from that of the geologist, although attention has been given as far as possible to the origin of the materials as well as to their mineral composition. In this arrangement all rocks used as road materials have been separated into three general groups or classes, according to their geologic character, these groups being again divided into types and families.

Table VII

GENERAL CLASSIFICATION OF ROCKS

Class.	Type.	Family.
I. Igneous	1. Intrusive (plutonic)	a. Granite b. Syenite c. Diorite d. Gabbro e. Peridotite
	2. Extrusive (volcanic)	a. Rhyolite b. Trachyte c. Andesite d. Basalt and diabase
II. Sedimentary	1. Calcareous	a. Limestone b. Dolomite
	2. Siliceous	a. Shale b. Sandstone c. Chert (flint)
III. Metamorphic	1. Foliated	a. Gneiss b. Schist c. Amphibolite
	2. Non-foliated	a. Slate b. Quartzite c. Eclogite d. Marble

With the exception of rocks of the second class, where chemical distinctions prevail, structural features indicating mode of origin define the type, and mineral composition the family. Photomicrographs, illustrating the structure and mineral composition of the principal rocks are given in Figs. 65 to 78, inclusive.

Igneous rocks. All rocks of the igneous class are presumed to have solidified from a molten state, either upon reaching the earth's surface or at varying depths beneath it. They vary in color from the light gray, pink, and brown of the acid granites and syenites to the dark steel gray or black of the basic gabbro, peridotite, diabase and basalt. The darker varieties are commonly called "trap." This term is in very general use and is derived from *trappa*, Swedish for stair, because rocks of this kind on cooling frequently break into large tabular masses, rising one above the other like steps.

The sedimentary rocks as a class, represent the consolidated products of former rock disintegration, as in case

FIG. 65.—Granite.

of sandstone, conglomerate, shale, etc., or they have been formed from an accumulation of organic remains chiefly

FIG. 66.—Andesite.

of a calcareous nature, as in true limestone and dolomite (Fig. 72). Loose or unconsolidated rock débris of a pre-

Fig. 69.—Peridotite.

vailing silicious nature comprise the sands, gravels, finer silts, and clays. Shell sands and marls, on the other hand, are mainly calcareous and are formed by an accumulation of the marine shells and of lime-secreting animals.

Sedimentary rocks.

Such terms as flagstone, freestone, brownstone, bluestone, graystone, etc., are given generally to sandstones of various color and composition, while puddingstone, conglomerate, buccia, etc., apply to consolidated gravels and coarse feldspathic sands.

The calcareous rocks are of many colors, according to the amount and character of the impurities present.

Metamorphic rocks are such as have been produced by the prolonged action of physical and chemical forces (heat, pressure, moisture, etc.) on both sedimentary and igneous rocks alike. The foliated types (gneiss, schist, etc.) represent an advanced stage of metamorphism on a large scale and the peculiar schistose or foliated structure is due to the more or less parallel arrangement of their mineral components (Figs. 73, 74, 75). The nonfoliated types (quartzite, marble, slate, etc.) have resulted from the alteration of sedimentary rocks without materially affecting the structure and chemical composition of the original material. (Fig. 78).

Metamorphic rocks.

The color of metamorphic rocks varies between gray and white of the purer marbles and quartzites to dark gray and green of the gneisses, schists, and amphibolites. The green varieties are commonly known as greenstones or greenstone schists.

The family groups given in Table VII may be further subdivided into many subfamilies or varieties—as, for instance, biotite-granite, hornblende-schist, etc., according to characteristic primary mineral constituents, a list of which is given in Table VIII, together with their approximate chemical composition.

Primary mineral constituents.

Fig. 72.—Crystalline Limestone.

Table VIII

PRIMARY MINERAL CONSTITUENTS OF ROCKS USED FOR ROADMAKING

Name.	Chemical Composition.
Quartz	Silica
Orthoclase (microcline)	Silicate of alumina and potash
Plagioclase	Silicate of alumina, lime, and soda
Augite	Silicate of lime, magnesia, iron, and alumina
Hornblende	Silicate of lime, magnesia, iron, and alumina
Calcite	Carbonate of lime
Dolomite	Carbonate of lime and magnesia
Biotite	Hydrous silicate of alumina, iron, magnesia, and potash
Muscovite	Hydrous silicate of alumina and potash
Magnetite	Magnetic oxide of iron
Rock glass	Variable
Garnet	Silicate of iron, alumina, and lime
Olivine	Silicate of magnesia and iron
Pyrite	Disulphide of iron
Hematite	Oxide of iron
Hypersthene	Siliacte of iron and magnesia
Titanite	Titano-silicate of lime
Apatite	Phosphate of lime
Zircon	Silicate of zirconia

Physical properties of rocks.

The physical properties of the principal road-making rocks are given in Table IX, in which they are arranged according to the classification given in Table VII, with their more important varieties.

Table IX

PHYSICAL PROPERTIES OF ROCKS FOR ROADMAKING *

Rock Varieties.	Physical Properties.				
	Per Cent Wear.[1]	Toughness.[1]	Hardness.[1]	Cementing Value.[1]	Specific Gravity.[2]
Granite	3.5	15	18.1	20	2.65
Biotite granite	4.4	10	16.8	17	2.64
Hornblende granite	2.6	21	18.3	30	2.76
Augite syenite	2.6	10	18.4	24	2.80
Diorite	2.9	21	18.1	41	2.90
Augite diorite	2.8	19	17.7	55	2.98
Gabbro	2.8	16	17.9	29	3.00
Peridotite	4.0	12	15.2	28	3.40

(*Table IX continued on p.* 109.)

Fig. 75.—Mica-schist.

TABLE IX*—*Continued.*

Rock Varieties.	Physical Properties.				
	Per Cent Wear.[1]	Toughness[1]	Hardness.[1]	Cementing Value.[1]	Specific Gravity.[2]
Rhyolite	3.7	20	17.8	48	2.60
Andesite	4.7	11	13.7	189	2.50
Fresh basalt	3.3	23	17.1	111	2.90
Altered basalt	5.3	17	15.6	239	2.75
Fresh diabase	2.0	30	18.2	49	3.00
Altered diabase	2.5	24	17.5	156	2.95
Limestone	5.6	10	12.7	60	2.70
Dolomite	5.7	10	14.8	42	2.70
Sandstone	6.9	26	17.4	90	2.55
Feldspathic sandstone	3.3	17	15.3	119	2.70
Calcareous sandstone	7.4	15	8.3	60	2.66
Chert	10.8	15	19.4	27	2.50
Granite gneiss	3.8	12	17.7	26	2.68
Hornblende gneiss	3.7	10	17.1	30	3.02
Biotite gneiss	3.2	19	17.5	41	2.76
Mica schist	4.4	10	17.3	30	2.80
Biotite schist	4.0	....	....	16	2.70
Chlorite schist	4.2	....	....	24	2.90
Hornblende schist	3.7	21	16.5	53	3.00
Amphibolite	2.9	10	19.0	29	3.00
Slate	4.7	12	11.5	102	2.80
Quartzite	2.9	19	18.4	17	2.70
Feldspathic quartzite	3.2	17	18.3	21	2.70
Pyroxene quartzite	2.3	27	18.6	17	3.00
Eclogite	2.4	31	17.4	21	3.30
Epidosite	3.6	16	16.0	47	3.03

* Condensed from an extensive table of the mineral composition of rocks compiled by the Bureau of Chemistry of the U. S. Dept. of Agriculture.

1. The tests for obtaining these values were outlined in pages 97–100.

2. The specific gravity is the weight of the material compared with that of an equal volume of water, and is obtained by dividing the weight in air of a rock fragment by the difference of its weight in air and water. Given the specific gravity, the weight per cubic foot of a rock is found by multiplying this value by 62.5 pounds, the weight of a cubic foot of water.

Fig. 78.—Quartzite.

From the results of the extensive series of tests of road materials made by various methods by the Office of Public Roads, the following conclusions have been reached:*

Conclusions regarding paving stones.

1. Igneous and metamorphic rocks, owing to a higher degree of crystallization and a preponderance of silicate minerals, offer a greater resistance to abrasion than nearly all varieties of sedimentary rocks.

2. The coarse-grained intrusive rocks of the igneous class are harder, but break more readily under impact than the finer-grained volcanic varieties of like mineral composition.

3. The deleterious effect of atmospheric weathering on the wearing qualities of rocks has been demonstrated.

4. The cementing value of rocks is, to a certain degree, measured by the abundance of secondary minerals resulting from rock decay.

5. Metamorphic rocks have, as a rule, a low binding power, owing to a regeneration of secondary minerals and to the effects of heat and pressure. The foliated types part readily along planes of schistosity, and therefore are not well adapted to road construction.

6. The quantitative mineral analysis of rocks serves to a certain extent as a measure of their useful properties for road construction.

The principal varieties of rock employed for paving-blocks are the granites, basalts, sandstones, and limestones, because of the facility with which they split into the desired shapes; for broken-stone pavements all varieties of rock are used, including the flints and gravels.

Principal varieties of roadmaking rocks.

Granite is an unstratified igneous rock, consisting of quartz, feldspar, and some form of mica, or hornblende, in addition to which essential constituents one or more accessory minerals may be present. The character of the granite is determined principally by its essentials, but the accessories have much to do with its qualities.

Granite.

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* U. S. Department of Agriculture, Office of Public Roads, Bulletin No. 31.

The colors of granite are white, gray, various shades of red, and green, the color being generally fixed by the feldspar, but the mica is often a governing characteristic, the presence of muscovite (potash mica), making a granite light, while biotite (iron-magnesia mica) has the opposite effect.

The durability of granite depends to a great extent upon the character of the feldspar present, too much of it rendering the granite soft and tough, but liable to decomposition, while a large amount of quartz will make it hard and brittle. The susceptibility to polish and its ability to resist the action of the elements depend greatly upon the accessory components; hornblende permits it to take a high polish, while pyroxene, being very brittle, often gives a pitted appearance to an otherwise smooth surface.

The structure of granite varies considerably from coarse to fine and is termed the *holocrystalline*, which implies that it is made up exclusively of crystalline particles having clear, well-defined boundaries. A fine-grained stone, of small and evenly distributed grains, is compact in texture, excluding air and moisture, both of which are destructive agencies to all minerals, and may be more easily cut and polished than a coarse-grained stone. On account of its peculiar structure, granite can easily be broken into blocks of any desired shape or size. It is specially adapted in roadwork for paving blocks, curbing, flagging, basin-heads, crossing stones, and gutter stones; it is also crushed and used for manufacture of concrete and artificial stone.

The term "granite," which should in a strict sense not be applied to any stone not containing mica, is often applied commercially and popularly to what are known as the gneisses (foliated and bedded granites), syenite, diorite, gabbro, and other crystalline rocks whose uses are similar.

Syenite (so named because it was first found in Syene, Egypt) consists of feldspar and hornblende, with or without quartz. It is massive and furnishes excellent material for paving blocks, but is seldom found or used in this country.

Diorite is composed of a crystalline mixture of oligoclase (soda and lime feldspar) and hornblende with magnetic iron

and apatite, and occurs under conditions similar to syenite. When the component minerals are fine-grained and compact they make a very satisfactory material for broken-stone roads.

Basalt.

Basalt is one of the names given to a large group of unstratified eruptive rocks, commonly called trap-rock (See page 102). The trap-rocks are generally close-grained and compact in texture; they are hard and tough and break irregularly and are usually difficult to work. In color they are dark gray, dark green, or grayish black, the dark color being due to a larger proportion of magnetite, which also contributes to the high specific gravity of these rocks. The trap-rock of the Palisades on the west shore of the Hudson river split easily into blocks, and has been extensively and satisfactorily used for paving in the cities of New York and New Jersey.

Sandstone.

Sandstone is formed by the decomposition on disintegration of rocks. The pockets of sand often found in beds of earth or limestone are the results of boulders being surrounded when these deposits of clay or stone were first made, and which long afterwards decayed, leaving in their places these pockets of sand, whose composition depends upon the minerals contained in the original rocks.

Sandstone is formed by grains of sand being deposited in beds by some agency and afterwards compacted. The sand proper is almost all quartz, as this mineral is indestructible from the ordinary action of the elements, while the cementing portion of the original rock has generally been decomposed and a new substance formed. The solidification of the stone is caused by great pressure, partial solution, fusion of some of its own parts, or by the infiltration of some cementing material, such as silica lime, or the oxides of iron. It is generally found in layers of variable thickness separated from each other by some softer material, the thickness of these layers probably depending upon the time one force acted continuously upon the sand, the softer deposits being made during the intervening period.

The texture of the stone varies according to the sizes of the sand grains.

Sandstones are of many colors, the most common, however, being gray, yellow, and red. These colors are determined by the different combinations of iron; the red being due to peroxides, and the yellow to hydrous peroxides. Some varieties will change color upon exposure to the air or the application to heat, on account of the oxidation of the iron.

In street construction sandstones are used for curbing, cross-walks, flagging and for paving the roadway.

Limestones. Limestone, like sandstone, is a sedimentary rock, but differs from it very much in its formation. Water flowing down from a rough mountainous country carries with it a large amount of matter both in solution and in suspension. As the stream reaches any larger body of still water its velocity gradually decreases and that portion is suspension is deposited, the coarser and heavier near the shore and the finer farther out. Calcareous matter, as a rule, being soft, is generally fine, and is borne from a distance and finally deposited as silt.

All these flowing streams contain a considerable quantity of lime in solution which, being in part precipitated, serves to consolidate the silt. From this same source certain marine animals derive their supply for their shells. Upon the death and decomposition of the animal life the shells and corals are left and, breaking up, in time form calcareous banks which later on become beds of limestones of more or less fragmental nature.

These formations are generally in well-defined beds nearly level when not disturbed by any subsequent force, but when they have been acted upon by some of the forces so frequent during the formation of the earth's crust, the strata are found at all angles with the horizontal.

Limestones differ greatly in structure, from the variety highly charged with fossils to the hard compact rocks denser and heavier than granite. They also vary in color according to the iron and carbonaceous compounds that may be present.

Silica and clay are often found in composition, and when they exist in quantities exceeding ten per cent the stone is said to be "hydraulic." That is, upon being burned and ground

it can be made into mortar that will harden under water, a property not belonging to ordinary limestones.

Marble is a crystalline limestone of such a character as to be capable of receiving a high polish.

Of the other materials used in road making, wood is treated in Chapter XVI; asphalt, in Chapter XVII, and concrete in Chapter XVIII.

Sand and clay.

Sand is an aggregation of loose incoherent grains, crystalline in structure and angular in shape, of silicious, argillaceous, calcareous, or other material, derived from the disintegration of rocks or other mineral matter, and unmixed with earth or organic matter.

Clay consists of a hydrated silicate of alumina in combination with other substances derived from the feldspathic rocks, which by their disintegration and decomposition have formed the clay. Pure clay is soft, white and opaque; has a characteristic odor, is infusible, and insoluble either by water, nitric or hydrochloric acids. It may be converted by water into a doughy, tenacious, plastic paste; it absorbs water, but when burned at a sufficiently high temperature it becomes hard and gritty, and loses almost wholly this property of combining with water.

With the single exception of ordinary earth or loam, sand and clay in combination form probably the lowest type of material available for road purposes.

Sand of itself, while at its best in winter and spring, does not ever have sufficient stability to sustain traffic over it, and clay, of itself, is open to the same or greater objection than loam. It is possible, however, to combine sand with clay in such a manner that under moderate traffic and favorable climatic conditions a fairly serviceable road may be obtained. (See Chapter VII.)

The principal use of sand is as a foundation for broken stone, a cushion and bed for stone paving-blocks, and as a joint filling. For these purposes it is most suitable, because when confined so that it cannot escape or spread, it possesses the valuable property of incompressibility, and mobility, or the

property of assuming a new position when any portion of it is disturbed.

Sharp sand, with angular grains, is much better than sand with rounded grains, although it is often difficult to obtain. The sharpness of sand can be determined by rubbing a few grains in the hand or by crushing it near the ear and noting if a grating sound is produced.

The sand for bedding rocks and for jointing should be free from loam or clay. The clearness may be tested by rubbing a little of the dry sand in the palm of the hand and, after throwing it out, noticing the amount of dust left in the hand. The cleanness of sand may also be judged by pressing it together between the fingers while it is damp; if the sand is clean, it will not stick together, but will immediately fall apart when the pressure is removed.

Gravel.

Gravel is an accumulation of fragments of stone, or small stones, varying in size from a pea up to an egg. It is often intermixed with other substances, such as sand, clay, loam, etc., from each of which it derives a distinctive name.

As a rule, gravel is unserviceable for roadmaking, mainly due to the smoothness of the surface of the pebbles, preventing their binding together in the manner of broken stone. There is also an absence of dust or other cementing material, and even if such binder is furnished it is difficult to effectively hold the rounded and polished surfaces of the pebbles together.

Free Government tests.

At the present time there should be no difficulty in determining the relative values of stones for road purposes in any locality. The Office of Public Roads, of the United States Department of Agriculture, undertakes to make tests and analyses of samples of stones, without charge, and to give advice as to their value for roadbuilding purposes.

CHAPTER VII

EARTH, GRAVEL, SAND AND CLAY ROADS

Earth Roads

The term "Earth Roads" includes all those constructed of natural soil, whether loam, clay or sand, without a crust or other road covering. The earth road is the cheapest form of road as regards first cost, and is generally the pioneer in any new country. In its simplest form it consists of dirt from the sides, simply thrown up into the center, with little or no regard for the formation of a crown for the lateral shedding of rain-water. The bulk of the country roads of America are made of earth alone, and as a well-made earth road forms an excellent foundation for a graveled or a broken-stone road, and its construction is in many cases preparatory to a more permanent improvement, the importance of scientific design and construction will be easily seen.

Fig. 79.—Earth Road With Flat Surface, as ordinarily constructed.

If, as is often done, the loose earth be thrown into the middle of the road to be compacted by the wheels of the traffic, the action of the wheels will be to cut it, or at least to pack it in a very uneven manner, producing a surface uneven and full of ruts, which will hold water and ultimately cause the destruction of the road. In case, however, the surface be properly rolled, it may usually be made sufficiently firm to hold up the wheels and retain its form under the traffic, and if kept free from ruts until thoroughly compacted will thus be rendered much more capable of resisting the penetration of water and shedding it into the side gutters.

The first step in construction.

The first step in the construction of a new earth road in most localities is to clear the surface over the entire width of all stumps, brush, vegetable matter, rocks, and boulders. These should be removed and the resulting holes filled in with suitable materials thoroughly tamped or rolled, before the road embankment is commenced. No perishable material should be used in forming the permanent embankment.

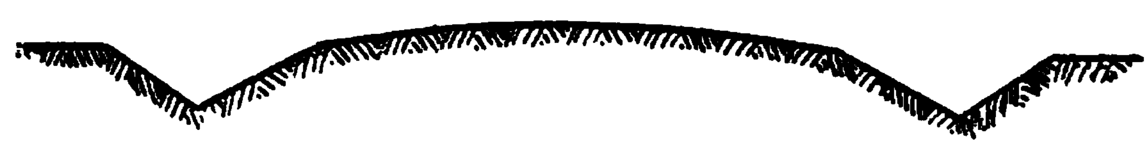

FIG. 80.—Proper Cross-section for Road in Loamy Soil. Crown 1 inch per foot.

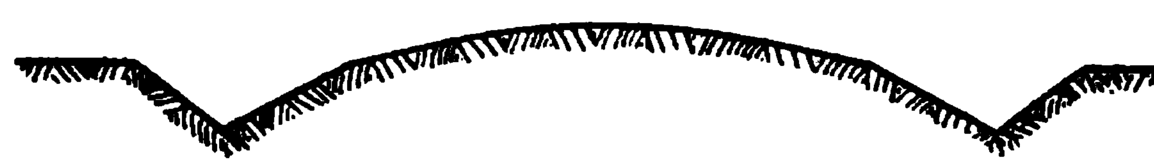

FIG. 81.—Proper Cross-section for a Clay Road. Crown 1½ inches per foot.

FIG. 82.—Cross-section of Road as usually left by the grader, with the last cut of the blade at 2. It should have been left as in Fig. 81, with the last cut of the grader blade in position 1.

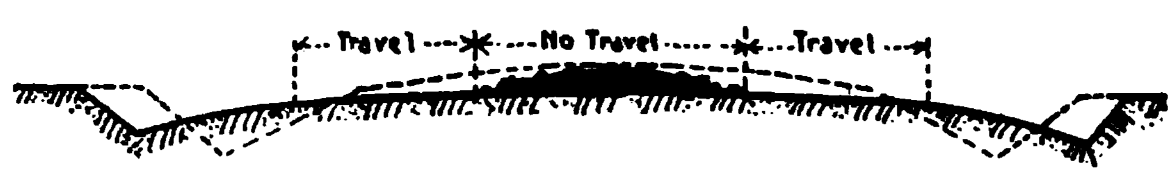

FIG. 83.—Cross-section of Road Graded Too Wide, with a pile of loose dirt and sods in the center. The travel naturally takes the sides where the earth has been scraped off by the grader.

In a wet district or where the soil is naturally damp the trees and scrub should be cleared the full width of the right-of-way to allow of proper evaporation, but in hot and dry districts, where the comfort of travelers must be considered, it is well to leave growing trees on each side of the roadway.

Whenever the subgrade soil is found unsuitable it should

be removed and replaced with good material rolled to a bearing. The roadbed having been brought to the required grade and crown, should be rolled several times to compact the surface and all irrequalities leveled up and re-rolled. On this prepared subgrade the earth should be spread, harrowed, if necessary, and then rolled to a bearing by passing the road roller a number of times over every portion of the surface.

Preparation of roadbed.

In level countries and with narrow roads enough material can generally be excavated in forming the side ditches to raise the roadway above the subgrade. If not, the required earth may be obtained by widening the side excavations, or from cuttings on the line of the new roadway, or from borrow-pits close by. When the earth is brought up to the final height it is again harrowed, then trimmed by means of road levelers or road machines, and ultimately rolled to a smooth and solid surface, the cross-section of the roadway being maintained during the last rolling stage by the addition of earth as needed. Before the earth road is opened to traffic, the side ditches should be cleaned and left with the drain tiling in good working order.

Preparation of road surface.

On account of the loose character of the material, earth roads require most careful design in order that the road may be kept dry. Water is the great destroyer of earth roads, and drainage is especially important in their proper making and maintenance because the material of the roadway is more susceptible to the action of the water and more easily destroyed than any other material used in the construction of roads. If not properly drained the rain and snow soften it and it soon becomes impassable mud. If, on the other hand, water is allowed to run on the road surface, it will soon wash away the earth and form gullies.

Drainage.

As stated in Chapter V, the prime necessity of every road is thorough drainage; without it, the road cannot long remain intact. In the construction of earth roads it is, in fact, the most important matter to be considered; drainage alone will often change a bad earth road to a good one, and the best

road may be quickly destroyed by the absence of proper drainage.

Side ditches are provided for country roads in most cases; but these are often imperfectly made, and even the best side drains are usually inadequate to relieve the road from its soggy, impassable condition. Nothing brings relief except the slow process of evaporation, and even when a road is dried by the sun and wind it is generally left in a rough, rutty condition.

With wet or clayey roadways surface drainage alone is not sufficient. Without underdrainage the crown of such roadways will dry only by the action of the sun, during which time the topping becomes more and more rutted by the passing traffic. A subdrain in such soils will not prove efficient for more than about 12 feet on each side; hence, two lines of longitudinal subdrains are needed on those roads that pass through wet places, low-lying lands, or clayey soils. They should have an average fall of about 1 in 100, with a minimum of 1 in 1000. At short intervals of about 36 to 100 feet apart, are placed cross drains to discharge the water into the side ditches, which may have a fall up to 1 in 30. It is advantageous to bed these tiles in well-rammed brick fragments and to cover them with stone, taking care that nothing interferes with their free discharge. The bottom of the tiles should be laid both to the proper grade and below the frost line, after which the tile trench is filled up to subgrade with clean gravel, small stones, or broken stone or bricks. The cross drains should be made of unglazed tiles, with outlet sections of vitrified culvert pipes. Regular branch pipes should connect the longitudinal and cross tiles. On level reaches the lateral roadway slopes for surface drainage should not be less than 1 in 24, and side ditches should be provided, when necessary. A rapid discharge of the side ditches is of the utmost importance to roadway preservation.

Too many trees should not be allowed on the sides of dirt roads, because they impede the drying action of the sun and wind, and their water-seeking roots are apt to creep into the drains and thus obstruct or prevent the junction of the tiles.

The water having been taken from under the road and off the road it is next necessary to carry it across and away from the road by proper culverts. These should be put in at every point that water can be carried away from the road by natural channels, and their location will be regulated by the position of these channels. Probably in no way is more money wasted in road work than in the building of cheap and temporary culverts. Nothing but the best should be built even if something else must be sacrificed. (See Chapter V.)

Culverts.

The great point in having good roads is the care of them after they are made. It is absolutely necessary in order to have good roads that it must be the constant duty of someone to look after them after the road is built, especially during and following a rain, that water may be kept off as far as possible.

Maintenance and repair.

Dirt roads are readily repaired by a judicious use of road machines and road rollers. Ploughs and scoop scrapers should should not be used for this purpose, as they would loosen the portion of the road that was already consolidated by the traffic. Repairs should be attended to, particularly in the spring of the year, and whenever the roadway becomes rutted.

Any small breaks in the surface must be immediately repaired and ruts filled and smoothed before they become serious.

The work required to keep a road in repair depends upon the nature of the surface and the efficiency of the drainage. A well-constructed road of good material will be much easier and less expensive to keep in repair than one in which the surface is not firm enough to resist the cutting action of the traffic, or which has a surface of material readily softened by the action of water which may fall upon it.

Earth roads under the most favorable conditions are expensive to maintain, and especially so under the common system of repairing once or twice a year, or at long intervals. This system is not only costly in the work required, which usually amounts to a practical reconstruction of the road each time repairs are undertaken, but it is ineffectual in that the road

for the larger portion of the time is out of repair and in bad condition, even if the work of construction has been well done, which is not usually the case where this method obtains.

The only way to keep an earth road in good condition is by the employment of men whose business it shall be to continually watch the road, and make such small repairs as may be necessary from time to time. The small washes that may occur during heavy storms, ruts formed by wagons traveling in the same tracks, or in passing over soft spots when the road is wet, or any small breaks in the surface of the road, should be at once attended to and carefully filled with new material.

When there are long-continued rains, or when the ice and snow of winter are melting in the spring, an earth-road surface will necessarily be more or less softened and cut by passing vehicles; and at such time a road of this character cannot be maintained in the same condition as in dry weather, or in the condition which would be possible with a less permeable surface, but if at the beginning of the wet period it be in proper form and if the drainage be efficient, the injury to the road, as well as the duration of the bad condition, will be reduced to a minimum. As soon as possible after such a wet period, the roads should be gone over with the scraper, or a "split-log drag." This should be done before the ground becomes thoroughly hard and dry, as it will work more freely, and may be compacted much closer than afterward.

The difficulty in the cost of maintaining the road will of course vary with the nature of the traffic that passes over it. A road for light driving will be much easier to keep in repair than one used for heavy loads, and as the amount of heavy traffic becomes greater, the economy of the earth surface is lessened, and the desirability of the substitution of a more durable wearing surface increases.

The width of the wheel tires upon which the loads are carried is also important in its effect upon the cost of keeping a road in repair. Narrow tires cut and rut the surface of a road, while those of sufficient width act as rollers to compact the material.

Gravel Roads

Gravel furnishes a very acceptable substitute for stone as a material for the construction of roads with a moderate amount of travel, and, when well constructed, a gravel road is a satisfactory one. It has to commend it its ease of laying and ease of repair, but it has not the durable qualities of a good broken-stone road when subjected to heavy travel.

Gravel roads may be roughly subdivided into two classes:

1. Those made of gravel which has been crushed and screened in the same manner as stone. This class of road is constructed exactly like a stone road under the same conditions, as described in Chapter VIII.

2. Those made of gravel which is used practically as it comes from the pit.

Gravel roads can be constructed, as they most often are, by simply dumping the unscreened gravel on the road and letting the traffic do the rest, but this is a poor and expensive method. They can be made by spreading the gravel in one course only, but so made are not satisfactory or lasting. To make a really satisfactory and economic gravel road, the gravel should be much the same size as is the stone used for stone roads, and should be spread in two courses of not over 6 inches each, and rolled with a 7- or 10-ton roller.

Gravel.

Gravel to be used on roads should be sharp and comparatively clean. If it runs very unevenly in the pit it should be screened; the material not going through the 1½-inch screen being used for the first course and that going through for the second. Even if the gravel runs evenly there will always be some large stones and these should be thrown out. No stone larger than 3 or 4 inches should be allowed in the road even in the first course.

After screening, the sand or clay left in the gravel should be no more than just enough to fill the voids in the stone, and the less it takes to do this the better the gravel is for road purposes. After spreading, the gravel should be gone over once or twice with a harrow to mix it thoroughly and

to get rid of small pockets of sand or dirt, which, however, can often be prevented by careful selection in the pit.

Fig. 84.—Gravel Road in Ohio; Dries Quickly After a Rain

There are a few pits from which very satisfactory gravel roads can be built by using the gravel just as it occurs without

screening or crushing. A community that has such material is blessed above all others. Even the best of material, however, must be properly laid and rolled if permanent and economical results are to be secured. It does not pay to throw gravel or stone on the road in the old slipshod way.

The subgrade should be prepared in the same way as for

Fig. 85.—A Gravel Road under Construction in the Old Way. The gravel is spread but no shoulders have been made to hold it, and no attempt is made to get gravel of an even quality. Such a road soon wears into holes which must be filled before the road is in good condition for travel.

First course.

crushed stone. Material for the first course should consist of gravel of 1½ inch to 3½ inches diameter and not more than 30 per cent of material less than 1½ inches in size. This should be spread evenly and rolled and finished in the same manner as the first course of stone. If it does not consolidate add more clay and roll again until it is firm and hard with an even cross slope.

The second course of gravel should consist of the gravel and sand passing the 1½-inch screen, and should contain not

over 20 per cent of sand or clay. This should be spread evenly to 1½ times the depth required, and harrowed and raked until uniformity in the mixture is secured; then rolled until the whole is firm and hard, clay being added when necessary to make the gravel compact.

Second course.

Uncrushed gravel needs no third or binder course, and when the second course is rolled thoroughly and is smooth and hard it is ready for travel.

Sandy Roads

There are many miles of sandy roads in different parts of the country, and the remarks as to drainage, shaping, etc., do not apply to them in their natural condition. The wetter they are kept the better they are. Sand, when confined, will support almost any weight, the objection to sand alone as a road material lying in the total absence of any binding or cementing qualities. Sandy roads are good only when damp. It is useless to form or crown sand roads, as they do not require drainage. They should be made either flat, or lower in the center than at the sides, and trees and undergrowth should be allowed to grow as near the road as possible, as they help to retain the moisture. For temporary improvement of sandy roads a layer of cut straw, leaves, shavings, hay, bark, sawdust or any material that will accumulate and retain moisture and offer some resistance to the wheels, is of benefit, but for a semi-permanent improvement clay should be mixed with the sand in proper proportions, making a sand-clay road.

Clay Roads

The clay road in contrast to the sandy one, needs all the drainage and crown possible. Care should be taken to give a clay road a steeper cross slope, to make the ditches wide, to keep them open and clean, and to underdrain spots where the road is especially bad. These are the first essentials, but even with these precautions a clay road will never be a good road at all times unless it is treated with sand or dragged with a split-log drag.

Sand-Clay Roads

In some sections of the country sand and clay are the only road materials available, and while neither of these materials alone makes satisfactory roads, a proper combination of the two, with thorough drainage and suitable crown, will produce satisfactory results. Natural sand-clay roads may frequently be found in localities where the soil contains the right proportions of sand and clay. In sections of the country where the prevailing subsoil is composed entirely of clay, or, on the other hand, is of an extremely sandy character, these materials may be mixed in such proportions so as to overcome the most objectionable features of each. The mixing of sand and clay as a form of road construction has received careful study and is of great importance, especially to the Atlantic and Gulf States, where throughout large areas sand and clay are practically the only materials available for road building.

Essentials to success.

The essentials to success in this form of road are puddling and saturation. The clay must be rendered homogeneous by adding water until it is plastic like dough; and to this plastic clay, sand must be added to the point of saturation, but not beyond. What is meant by saturation may be clearly understood by reference to Fig. 86, which shows a magnified cross-section of sand-clay composition as found in a substantial sand-clay road.

No sand-clay road can satisfactorily withstand the severity of public travel without having first been reduced to a compact homogeneous mass of sand and clay, in which each grain of sand should be in touch with other grains on

Fig. 86 —Clay Mixed with Sand to the Point of Saturation, the angular sand grains being in contact.

all sides. Such a condition is secured only by a thorough mixing of the wet clay and sand, and rolling as the mixture dries. This forces the particles of sand together, and any excess of clay tends to rise to the surface, which must in turn be sanded and the operations repeated until the surface has become hard and compact, and free from clay-stickiness.

FIG. 87.—Sand-clay Mixture with not enough Sand, the grains not being in contact.

Causes of failure.

Sand-clay roads fail for various reasons. Imperfect drainage is the first cause. The imperfections may be in the cross-sectional drainage, the side ditches, or the drainage of the subgrade or roadbed. It is customary to give to a sand-clay road a little greater crown than is usually given to a macadam road, especially where the grade is above 3 per cent. The subject of side ditches should have more careful consideration than is usually given in case of macadam roads.

If the subsoil is clay, the bottom of the side ditches should be 18 inches or more below the crown, but if the land is rolling and the subsoil is sand of considerable depth, there is natural drainage and little or no side ditch will be required. Perhaps the most common error in drainage is the failure to drain properly and thoroughly all places where there are wet-weather springs. If necessary, the roadbed must be changed

FIG. 88.—Unsatisfactory Sand-clay Mixture, the sand grains being worn round.

so as to locate it upon dry gound, as even the deepest side ditches practicable may fail to give relief where such springs exist. It is important to avoid deep cuts and to carefully consider all probable sources of trouble. Water, beyond a very limited amount, adds nothing of value to the sand-clay road after it is completed. If water is always present, sand should be used without clay, as sand and water make a better road than sand and clay and water.

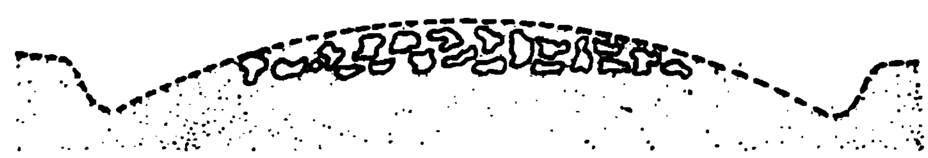

FIG. 89.—Cross-section of Road, showing lumps of clay placed on a sand subsoil and covered with sand.

Another cause of failure is the want of thorough mixing of even the proper proportions of sand and clay. Clay in lumps is useless; it should be uniformly saturated with sand to a depth of 10 inches. When ridges and holes appear, the high places should be leveled down and the holes filled in with sand.

In northern sections frost is another cause of failure and a

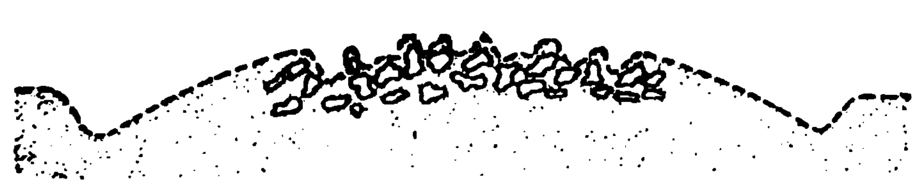

FIG. 90.—Cross-section of Road, showing displacement of lumps of clay when subjected to travel.

difficult one to deal with. It is temporarily destructive and for that reason the mixture must extend below the frost-line if the road is built on a clay foundation. Freezing disintegrates the sand-clay composition and makes of it a soft, slushy mud, which, however, repacks again after each heavy rain, although, as a rule, leaving the road surface somewhat rough.

Failure is sometimes due to the kind of sand selected. None except sand made up of angular grains is adapted to sand-clay road making. Sand with grains which are worn off round, or sand which has been ground up by the action of wheels or water until very fine, is unsatisfactory and often worthless. The use of such material should be avoided, as a perfect bond can not be effected (Fig. 88), and the road can not resist the

a. Typical Clay Road Before Improvement.

b. Sand-clay Road in Process of Construction, Gainesville, Fla.

c. Finished Sand-clay Road, Columbia, S. C.

FIG. 91. SAND-CLAY ROADS.

rolling action of wheels, the tendency being much the same as when pressure is applied to a mass of marbles.

Other causes of failure are the improper selection of clay and the improper treatment of the clay used. Ferruginous clays are the best, and chalky clays are the worst for road-building purposes. Some clays have a large percentage of sand to begin with and require less sand, while as a rule the chalky (sedimentary) clays have very little or very fine sand, and are more difficult to get fully saturated with sharp sand so as to become unyielding and homogeneous.

Another cause of failure in the use of this particular clay is the fact that it rarely has iron enough to cement or bind the material together; hence it is easily broken up and washed away or blown away as dust. There are many localities, especially in the South, where sand predominates, and the only clays to be found are sedimentary, often carrying a large percentage of very fine sand and scarcely any iron at all. It is difficult to build a first-class road of this material; but the first step should be to make the roadbed at least 20 inches above standing water in the ditches.

Lack of perseverance by the road builder is another cause of failure, and probably more failures result from this than from any other cause. The building of a sand-clay road is a process, not an instantaneous operation, and the builder may fail when well within view of success.

The building of sand-clay roads has passed the experimental stage, and it is no longer a question of doubtful procedure. The important things to be borne in mind are as stated, thorough mixing to the saturation point, and then properly shaping and rolling the road. This mixing might be done by the use of plows and harrows when the clay is wet; but it is customary to let the teams and vehicles of the traveling public accomplish it. This is the critical period in the construction of a sand-clay road, because care must be taken to secure an even amount of puddling, so that all the lumps of clay shall be broken and saturated with sand to a depth of 8 to 10 inches. If this can be done and the road is properly crowned as it dries, the result will be satisfactory.

It is, of course, impossible to state definitely the cost of this form of construction, as it will be found to vary with the price of labor, the length of haul, the width of roadway, and depth and nature of material. If however, the clay can be procured within a mile of the road which is to be improved, and the cost of labor is about $1 per day and teams $3 per day, the cost of constructing a 12-foot sand-clay road on a sand foundation, covered with clay to an average depth of 6 inches, would be approximately as follows for a distance of 1 mile: *

Cost of sand-clay construction.

Crowning and shaping road with road machine, using 2 teams at $3 and 1 operator at $1.50 per day for 1 day	$7.50
Loosening, $1173\frac{1}{3}$ cubic yards of clay with pick and shoveling into wagons, at 15 cents per cubic yard	176.00
Hauling $1173\frac{1}{3}$ cubic yards of clay, at 23 cents per cubic yard	269.86
Spreading clay with road machine, using 2 teams at $3 and expert operator at $1.50 per day for 3 days	22.50
Shoveling sand on clay, estimated at $\frac{1}{2}$ cent per square yard	35.20
Plowing, using 1 team at $3 per day for 4 days	12.00
Harrowing, using 1 team at $3 per day for 2 days	6.00
Shaping and dressing with road machine, using 2 teams at $3 and expert operator at $1.50 per day for 2 days	15.00
Rolling, estimated at $\frac{1}{2}$ cent per square yard	35.20
Total	$579.26

The estimated cost per square yard of road surface, therefore, when computed on the basis of this table, would be about 8 cents, or at the rate of $579.26 per mile.

The cost of building a sand-clay road on a clay foundation would not vary much from the figures given. The latter form of construction would probably be slightly cheaper, by reason of the fact that sand can be handled more economically than clay.

According to the experience of the Office of Public Roads, the cost of sand-clay construction in the South has been found to range from $200 to $1200 per mile, in most cases running from $300 to $800. In case changes of grade have to be made with consequent cuts and fills, the cost would be proportionately greater than the figures given above, but there can be no

* Office of Public Roads Bulletin, No. 27.

question, that under all circumstances this form of construction is cheaper than macadam.

Burnt-Clay Roads

In some sections of the country the only material available from which roads can be constructed is clay. This is especially the case in large areas in the South, where there is little or no sand and the clays are of a particularly plastic and sticky variety, locally known as "gumbo" and "buckshot." In such localities traffic is absolutely impossible during the wet season, as the wheels of heavy vehicles will sink to the hub. To meet this condition the U. S. Office of Public Roads made an experiment in the district of the lower Mississippi Valley, of burning the clay along the entire length of the road. By burning clay, even at a moderate heat, its sticky or plastic quality is destroyed, so that even in the wettest weather it will bear traffic. It was found by laboratory experiments that the clinkering point of the clay was sufficiently low to indicate that simple burning of the lumpy clays upon the road surface by means of open wood fires would accomplish the desired result. This permits the firing of the clay along the entire length of the road, thus avoiding the cost of hauling it, and at the same time gaining the advantage of burning the foundation of the road as well as the material to be placed upon it.

Gumbo clay is black, owing to the high percentage of organic or vegetable matter it contains. It is particularly sticky in its nature, and is almost wholly free from sand and grit. After it has been burned, however, the plasticity is entirely destroyed, and a light clinker is formed which, though not particularly hard, when pulverized forms a smooth surface and seems to wear well. It is not necessary that all of the clay out of which the road is to be constructed should be clinkered, but only a sufficient amount should be rendered nonplastic to neutralize the too sticky character of the native clay.

Good sound wood, as dry and well seasoned as it is possible

a. Pile of Wood and Clay Completed and Firing Begun.

b. Section of Road Burned.

FIG. 92.—BURNT-CLAY ROADS.

c. **Partial View of Finished Road.**

FIG. 92.—BURNT-CLAY ROADS.

Fuel.

to procure, is stacked at convenient intervals along the side of the road before the work is commenced. About one cord of wood is necessary for 8 linear feet of roadbed 12 feet wide. Brushwood, if it is dry, as well as chips, bark, old fence rails and railroad ties, coal slack—in fact any sort of fuel that can be easily and economically obtained, may be used to advantage with the cord wood.

Preparation of the roadbed.

After grading the road to an even width between ditches, it is plowed up as deeply as practicable. Furrows are then dug across the road from ditch to ditch, extending through and beyond the width to be burned; if it is intended to burn 12 feet of roadway, the transverse furrows should be 16 feet long, so as to extend 2 feet on each side beyond the width of the final roadway. Across the ridges formed between these furrows, which should be about 4 feet apart, the first course of cordwood is laid longitudinally so as to form a series of flues in which the firing is started—from 15 to 20 of these flues are fired at one time.

The best and soundest cordwood is selected for this course and should be laid so that the pieces will touch, thus forming

a floor. Another layer of wood is thrown irregularly across this floor, in crib formation, with spaces left between in which the lumps of clay are piled in such a way as to allow a draft for easy combustion.

After the lumps of clay have been heaped upon this floor, another course of wood is laid parallel to the first. The third layer is laid in exactly the same manner as the first, and each opening and crack should be filled with brush, chips, bark, small sticks, or any other combustible material. The top layer of clay is placed over all and the finer portions of the material are heaped over the whole structure.

The deep covering of clay which is thrown over all should be taken from the side ditches, and may be in lumps of all sizes, including the very finest material. It is spread as evenly as possible over the top in a layer of not less than 6 to 8 inches. Finally the whole is tamped and rounded off so that the heat will be held within the flues as long as possible.

It is necessary to get the fires well under way in the flues before the first layer of wood is burned through. The first action of the fire is to drive out the water contained in the clay before the actual burning and clinkering can begin. In burning the gumbo clays a great advantage is gained from the organic and vegetable matter which is contained in the clay, as that in itself aids combustion.

Firing.

The best results are obtained by firing all the flues of a section simultaneously and maintaining the combustion as evenly as possible. A supply of light, dry, kindling wood, or any easily inflammable material, should be at hand to prevent the fire from dying down in any one place.

After the firing is completed not only the portion of clay which forms the top of the kiln, but the ridges between the flues should be burned thoroughly, so as to form a covering of burnt clay 10 to 12 inches in depth, which, when rolled down and compacted, forms a road surface of from 6 to 8 inches in thickness. If properly burned, the material should be entirely changed in character, and when it is wet it will have no tendency to form mud.

When the material is sufficiently cooled the roadbed should be brought to a high crown with a road grader in order to allow for the compacting of the material. After this the rolling should be begun and continued until the roadbed is smooth and hard. The finished crown should have a slope of at least one-half inch to the foot.

The main advantages of this method of burning a road over its entire length are, first, that the cost of transporting the clay is avoided; second, that the subgrade of the road is burned as well as the material above.

Although this form of construction in the South up to the present time has been successful, it cannot as yet be said to have passed the experimental stage, so that the cost figures which will apply to the same work in all sections of the country cannot be given. The items of cost of the experimental road 300 feet long, as constructed at Clarksdale, Miss., are as follows:

Cost of burnt-clay construction.

30½ cords of wood at $1.30 per cord	$39.65
20 loads of bark, chips, etc.	6.00
Labor at $1.25 per day and teams at $3 per day	38.30
Total cost of 300 feet	83.95
Total cost per mile at this rate	1478.40

TOOLS USED IN CONSTRUCTION OF COUNTRY ROADS

Tools for Clearing and Grubbing

Bush hooks (Fig. 93).
Axes..
Grub hoes.
Mattocks (Fig. 94 and 95).
Stump-pulling machine.
Cross-cut saws.

Tools for Grading

Picks.
Grading pick (Fig. 96).
Clay pick (Fig. 97).
Shovels.
Ploughs (Fig. 98).

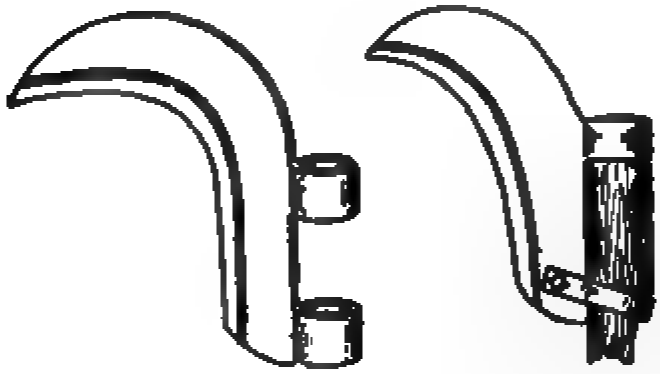

FIG 93.—Bush-hooks.

FIG. 94.—Axe Mattock.

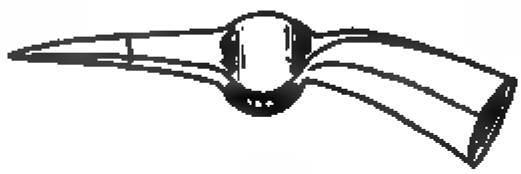

FIG. 95.—Pick Mattock.

FIG. 96.—Grading-pick.

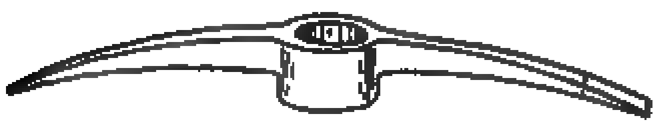

FIG. 97.—Clay-pick.

FIG. 98.—Hard-pan Plough.

There are many forms of ploughs, known as "grading ploughs," "road ploughs," "breaking ploughs," "hardpan ploughs," "township ploughs," etc., varying in construction

FIG. 99.—Roadscraper.

according to the kind of work they are intended for, such as loosening earth, gravel, hardpan, etc.

Wheelbarrows (Fig. 100).
Scrapers (Fig. 101-103).

These are made of wood or pressed steel and are employed in moving earth short distances, in maintenance and street-

FIG. 100.—Dirt Wheelbarrow.

cleaning work. The maximum distance to which earth can be wheeled economically in barrows is about 200 feet.

Scrapers

Scrapers are generally used for moving material after it has been loosened by ploughing. The two principal varieties are the drag and the wheel scraper.

Drag Scraper.—The scoop (Fig. 101) is made in three sizes, 3 and 7 cubic feet capacity. Some have metal runners on

Fig. 101.—Drag-scraper.

the bottom, others have a double bottom, which decreases draft and increases durability. Used for moving earth short distances, but unsuitable for building a bank of uniform

Fig. 102.—Drag-scraper with Runners.

solidity or for finishing an embankment, as each scraperful is deposited in a compact mass and the surface made with it is a succession of lumps and hollows. Sometimes used for

loading wagons, by means of an elevated platform and an excavated runway.

FLAT-BOTTOMED POLE OR TONGUE SCRAPER.—Made in two sizes, 36 and 48 inches wide. Used for leveling up the road surface in excavations, and in preparing the subgrade for pavements.

BUCK SCRAPER.—Made in three sizes, 3½, 4, and 5 feet wide, with capacity of 8, 10, and 12 cubic feet, respectively. An improvement over the common scoop scraper,

FIG. 103.—Wheel Scraper.

having the advantages of being more readily loaded to its full capacity, a better and more uniform distribution of the of the earth, more durable and more easily loaded.

WHEEL SCRAPERS (Fig. 103) consist of a steel box mounted on wheels and furnished with levers for raising, lowering, and dumping, all movements being made without stopping the team. Made in three sizes, with capacities of 9, 12, and 16 cubic feet.

ROAD GRADERS.—This is one of the various forms of road machines. It is also known as the "scraping grader" (Fig. 99), to distinguish it from the "elevating grader," and is a very important factor in the construction and maintenance of earth roads. It consists of a frame carried on four wheels, support-

ing an adjustable scraper-blade, the front end of which ploughs a furrow while the rear end pushes the earth toward the center of the road or distributes it uniformly to form a smooth surface. The blade is adjustable backward and forward and to any angle or height. It will work in almost any soil. It is hauled by horses and makes successive rounds or cuts until the desired depth of ditch and crown of road is obtained. There are several forms of the machine, differing in minor details, but all are intended for practically the same purposes.

ELEVATING GRADER, consists of a frame carried on four wheels, from which is suspended a plough and a frame carrying a wide traveling inclined belt. The plough loosens the soil and throws it upon the belt, which delivers it upon the embankment or into wagons. The machine is adjustable and is made in two sizes, delivering earth from 7 to 8 feet vertically and 14 to 22 feet horizontally.

It is a very effective machine for building open ditches, earth embankments, filling of wagons, and for highway work. By proper adjustment the machine will build broad and low or narrow and high embankments or will excavate a deep and narrow or a shallow ditch.

The larger machine will place 1000 cubic yards of earth in an embankment in ten hours, or will load 600 cubic yards into wagons in the same time. It is propelled by twelve horses, eight in front and four behind, or by a traction engine, and is operated usually by three men.

The smaller machine will grade a quarter of a mile of ordinary unbroken road per day, with a width of 25 to 30 feet and a crown of 12 inches at the center. It is drawn by eight horses and operated by two men.

These machines are specially adapted to building earth roads in a prairie country, for which purpose they are very largely used.

CARTS.—These carts are furnished with wide tires and the body is so balanced that the load is evenly divided above the axle. The average capacity is 22 cubic feet and the average weight, about 800 pounds.

DUMP CARS.—Made to dump on one or both sides or ends, and at the bottom. They are used singly or in trains, according

(*Courtesy of Western Wheeled Scraper Co.*)

FIG. 104.—Elevating Grader.

to the magnitude of the work, and are drawn by horses or tractors.

DUMP WAGONS.—The use of these wagons for moving excavated earth, etc., and for transporting sand, gravel, and other materials, materially shortens the time required for

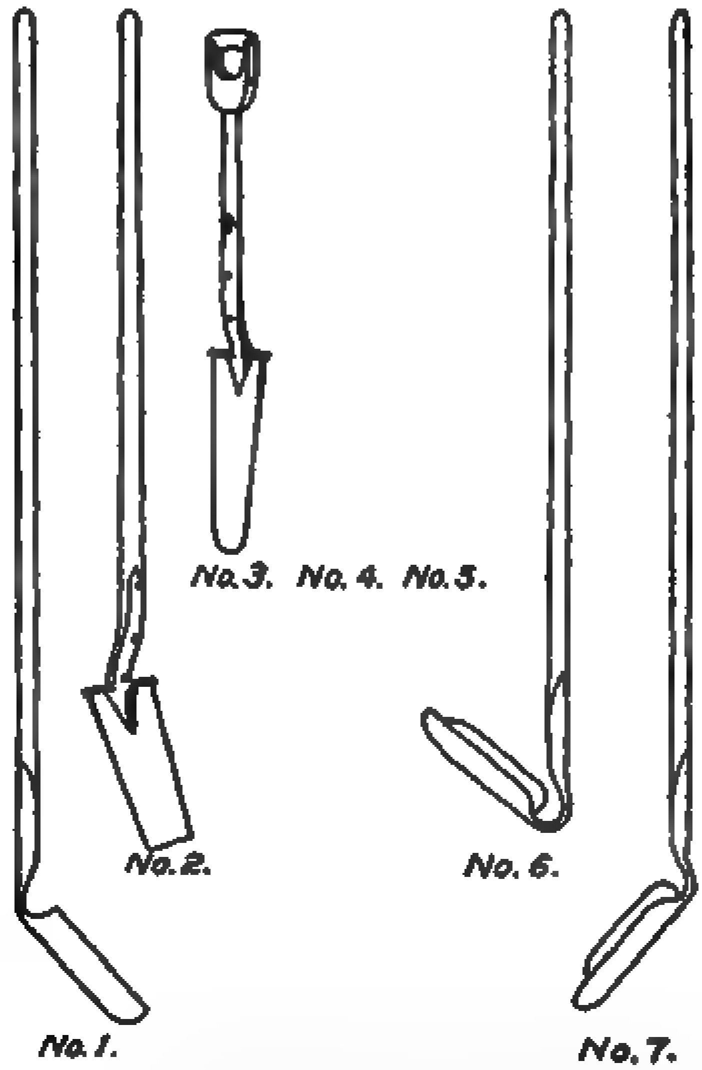

FIG. 105.—Draining-tools.

Nos. 3, 4, and 5, used for digging the ditch; Nos. 6 and 7 for cleaning and rounding the bottom of the ditch for round tile. No. 2 for shoveling out loose earth and leveling the bottom of the ditch. No. 1 for the same purpose when the ditch is intended for "sole" tile.

unloading over that required by the ordinary form of contractor's wagon. They are operated by the driver and have a capacity of from 35 to 45 cubic feet.

SURFACE GRADER.—Is operated by one horse and is used for removing earth previously loosened by the plough. It is also used to level off and trim the surface after scrapers.

ROAD LEVELER.—Is used for trimming and smoothing

the surface of earth roads and is largely employed in the spring when the frost leaves the ground.

Draining Tools.—These are used for digging the ditches and sloping the bottom to fit the drain-tiles.

The Earth-road Drag *

During the last few years a great deal has been written on the subject of the earth-road drag and its uses. Great changes in the general condition of many roads have been produced by the use of this simple tool, and several states have passed special laws allowing towns to make provisions for dragging all their clay roads after each rain.

The drag is not a cure for all evil roads, but if it is used at the proper time and on proper soils it will produce a road good for travel at times when the road, if undragged, would be an impassable mud hole.

Requisites for success.

The question as to whether to shape up a road before dragging is one that can only be decided by the character of the present road surface. If this is badly out of shape, narrow, with no ditches, or much higher on one side than on the other, it is best to plough it a furrow at a time and form it up with the road machine to shape approximately as shown in Fig. 80, which is the proper shape for a dragged road. Not quite as great a cross slope should be given in order to allow for material being pulled to the center by the drag. If the road is fairly well shaped and of the proper width it is ready for dragging at any time after the drainage has been attended to.

The road must have proper surface drainage or it is useless to drag it. Wherever the road is continually soft and spongy from underground water tile under-drain should be put in. Ditches should be kept clean and open at all times and proper culverts and bridges provided where necessary. The drag will smooth the surface so that water is quickly

* Condensed from Road Pamphlet, No. 2, "The Earth Road Drag," by Arthur R. Hirst, Highway Engineer, issued by the Wisconsin Geological and Natural History Survey.

carried to the ditches, but in order that dragging may be fully effective it is necessary that the water should be quickly carried away by the ditches and culverts.

(From Technical World Magazine)

Fig. 106.—A Country Road Dragged with the King Split-log Drag.

Description of drag.

The exact form or style of drag to be used is not the most essential part or road dragging. Almost any device will prove effective which will move a small amount of earth towards the middle of the road and at the same time smooth the surface. As the whole theory and effectiveness of road dragging depends on the moving of but a small amount of earth at a time, it is important that no road drag be used which is heavy. In fact, the lighter and more simple the drag the more effective it usually is.

A simple stick of timber or piece or railroad iron has proved useful for this work. V-shaped drags have also been used, but seem to be objectionable, on account of their heavy

draft. Perhaps the most effective form of drag is that known as the "split-log drag," which may also be made of two stout planks in place of the split log. Oak or other heavy wood should not be used where it is possible to get a log of lighter wood.

Figures 107 and 108 show two varieties of split-log drags which are so simple in construction that they can be made on every farm. The log should be from 8 to 12 inches in diameter and from 7 to 9 feet long. The holes in the front half of the log should be bored so that a slight slant forward is given to the lower part of the front face of the split log. The holes in the rear log are bored so that its flat face will be perpendicular to the sticks forming the connecting braces, which should be tapered at the ends so that they will fit snugly into the holes bored into the logs. The holes should not be less than 2 inches in diameter. The ends of the cross sticks should be split and wedges driven so as to secure the cross-braces in place. The wedges should be driven crosswise of the grain of the log or plank so as not to split it. A diagonal cross-brace is placed between the logs at the leading end to stiffen the frame of the drag. The distance from the face of the back log to the face of the front log should be about 2½ or 3 feet. The lower front edge or toe of the drag should be protected by a strip of old wagon tire, or other piece of iron about a quarter of an inch thick, 3 or 4 inches wide and about 4 feet long. This strip of iron should be bolted to the front log and the heads of the bolts countersunk. The strip of iron should not be carried the entire length of the front log.

Chains should be provided with which to haul the drag, arranged with a short and long hitch as shown in the sketch, so that the drag will travel at an angle of about forty-five degrees with the direction of the road.

Object of road dragging.

Before giving instructions for operating a drag, it is well to keep in mind the objects to be attained by this method of road maintenance, which are to smooth the surface of the road when it is soft and muddy, to move a small amount of moist earth to the center, and to maintain the crown or oval shape of the road.

FIG. 107.—Split-log Drag Recommended by the Wisconsin Geological and Natural History Survey.

(*From Technical World Magazine*)

FIG. 108.—The D. W. King Split-log Drag used extensively in Missouri.

The drag is not an implement to use to move large quantities or earth, nor does the maintenance of an earth road require the use of such an implement. A consideration of the theory of road dragging will help to make the use of the drag more fully understood.

Theory of road dragging.

If a sample of moist earth is taken from the traveled portion of a road over a clay soil, it will be found practically impervious to water.

Earth in this condition is what the clay workers call "puddled." It has been worked and reworked by the carriage wheels and animals' hoofs until nearly all the traveled portion of a sticky, muddy road is covered with a layer of this impervious, puddled earth.

As usually found on most of the roads, this puddled earth is full of holes and ruts, which are filled with water that cannot escape through the impervious soil. As long as the water remains the soil cannot dry out and the road is kept in a most uncomfortable if not impassable condition.

It is also a matter of observation that this puddled earth when compressed and dried becomes extremely hard. On these two facts, the imperviousness of puddled earth and its hardness when dried, rests the theory of road dragging.

The effect of dragging roads.

When the road drag is properly used it spreads out the layer of impervious soil over the surface of the road, filling up the ruts and hollows until a smooth surface is secured. As a small amount of material is always to be pushed to the center, a slightly rounded effect will be given to the road, which may be increased or decreased as desired by subsequent dragging. By forcing the mud into the hollows and ruts it is evident that the water must go out, which it does by running off to the side of the road. The drying out of the road is thus much facilitated and the road is made immediately firmer.

The effect of traffic over the road tends to press down and thoroughly compact each thin layer of puddled earth which the drag spreads over the surface every time it is used. After the first few draggings the road becomes constantly smoother and harder so that the effect of a rain is scarcely noticeable,

Fig. 109.—Where Brooks flow in the Wagon Ruts, showing how a dangerous quagmire gets its start.

Fig. 110.—Part of same stretch of Road after Dragging.
(From Technical World Magazine)

the water running off the surface, which is so smooth and hard as to absorb but little of it.

The following points are to be borne in mind in dragging a road.

Instructions for dragging.

Make a light drag, which is hauled over the road at an angle so that a small amount of earth is pushed to the center of the road.

Drive the team at a walk.

Ride on the drag; do not walk.

Begin at one side of the road, returning on the opposite side.

Drag the road as soon after every rain as possible, but not when the mud is in such a condition as to stick to the drag.

Do not drag a dry road.

Drag whenever possible at all seasons of the year. If a road is dragged immediately before a cold spell it will freeze in a smooth condition.

The width of traveled way to be maintained by the drag should be from 18 to 20 feet; first drag a little more than the width of a single wheel track, then gradually increase until the desired width is obtained.

Always drag a little earth towards the center of the road until it is raised from 10 to 12 inches above the edge of the traveled way.

If the drag cuts in too much, shorten the hitch.

The amount of earth that the drag will carry along can be very considerably controlled by the driver, according as he stands near the cutting end or away from it.

When the roads are first dragged after a very muddy spell the wagons should drive if possible to one side until the roadway has a chance to freeze or partially dry out.

The best results from dragging are obtained only by repeated applications.

The following suggestions for using the drag are taken from the monthly bulletin of the Missouri Board of Agriculture for April, 1906.

1. "The length of the chain, which is regulated by slipping it backward or forward through the hole in ditch end of drag,

regulates the hold taken on the earth. To make the chain longer is equivalent to putting weight on the drag. If the drag is too heavy shorten the chain."

2. "The position of the snatch hook, which attaches the double-trees. To move much dirt or cut small weeds hitch the hook close to the ditch end of the drag and stand as nearly on the end of the front slab as is safe. Drive very slowly when thus hitched. This one hitch seems to be the hardest to learn. The others suggest themselves."

3. "Position of the driver on the drag. To move dirt see above. In a soft spot stand on rear slab. On a hard spot stand on front slab and drive slowly. If the drag clogs with straw, weeds, sod or mud, step to a point as far as possible from ditch end of the drag. To drop dirt in a low place step quickly from ditch end to other extreme. To fill a low place or mud hole nicely is the severest test of skill with a drag."

4. "Presence or absence and sharpness or dullness of the steel. The steel may project half an inch below the wood at the ditch end of the steel, but should come up flush with the wood at other end of the steel. After a clay or gumbo road has been dragged four or five years the soil becomes so tough and putty-like that one must study it closely to know what to do. Sometimes the sharp edge of steel is used; sometimes the dull edge (holes are bored in both edges of steel so that it can be turned upside down and same bolt holes used), and sometimes the plain wood. This can be learned only by experience."

Conclusion.

To one unacquainted with the results obtained by the use of the drag it seems unbelievable that so much good can be done with so simple an instrument. No definite rule can be laid down as to the best time to drag. If traffic amounts to practically nothing the wetter the road is the better. Ordinarily however, it is useless to drag a road when it is so wet the mud flows or so dry that it pulverizes. The best time is when the mud passes along the front edge of the drag without balling or sticking and packs easily into ruts and holes under pressure from the rear log and subsequent travel. The best time may be as soon

as the rain stops on some roads and hours afterward on others. Each man must find out for himself, by experience on his own piece of road, the proper time to drag it. In general, it will be found best to start right after the rain, especially when first starting to drag a road into shape, as throwing clay into the ruts drives the water out and the road dries much quicker. It is a good thing, however, to drag a road at almost any time with almost any kind of drag.

CHAPTER VIII

BROKEN-STONE ROADS

A BROKEN-STONE road is one built of small fragments of stone laid on a suitable earth foundation and compacted together into a solid mass. It is uncertain just when this system of road construction was invented, but as near as can be ascertained, the first systematic construction of broken-stone pavements was carried on in France in 1764 by M. Tresaguet, who built many miles of such pavements in the latter part of the eighteenth century. In the early part of the nineteenth century two systems were introduced into England, the first by Telford, the second by Macadam. From these two pioneers of good roads, modern engineers have drawn the principles upon which all present-day broken-stone roads are built. Such roads are generally known as "macadam" roads; the material itself is often called "macadam," and the work of construction, "macadamizing." These roads are also sometimes called "telford" roads, but this term is more appropriately restricted to a particular form of rough stone foundation for a broken-stone road. Neither is the term "macadam" altogether appropriate as a synonym for a broken-stone road, but should strictly be used only to designate the foundation or lower course of a stone road composed entirely of small fragments.

Difference between methods of Telford and Macadam.

The difference between the methods of Telford and Macadam is mainly on one point and has been more dwelt upon than the similarity of their systems on many other points on which they both differed so widely from the practice of their predecessors. Both insisted on the necessity for the thorough drainage of the road-bed, a thing then utterly neglected; both made use of materials broken to gauge to form a solid hard surface of

uniform cross-section, and of a surface curvature just sufficient to throw the rain water off freely to the sides. The distinction usually drawn between the Telford system and that of Macadam is in the foundation of large stones upon which Telford generally laid the broken stone or gravel.

To Macadam is due the credit of having been the first to direct public attention to the necessity of the proper breaking and preparation of road materials, and to the possibility of forming with them a compact road surface nearly impenetrable to water, which can be laid so flat as to allow vehicles to pass freely over all parts of the road, and at the same time throw off the water.

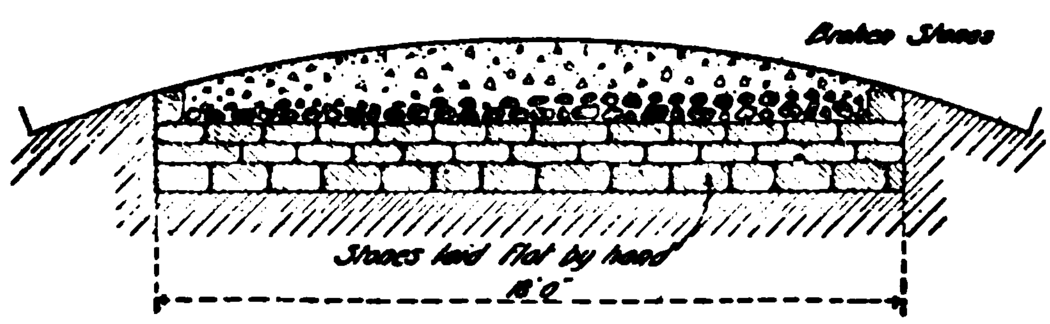

FIG. 111.—Cross-section of Typical European Roads before the time of Macadam.

What the process of roadmaking and road-mending was in the early part of the nineteenth century is thus described by Macadam:

"The practice common in England, and universal in Scotland, on the formation of a new road, is to dig a trench below the surface of the ground adjoining, and in this trench to deposit a quantity of large stones; after this a second quantity of stone, broken smaller, generally to about seven or eight pounds weight;

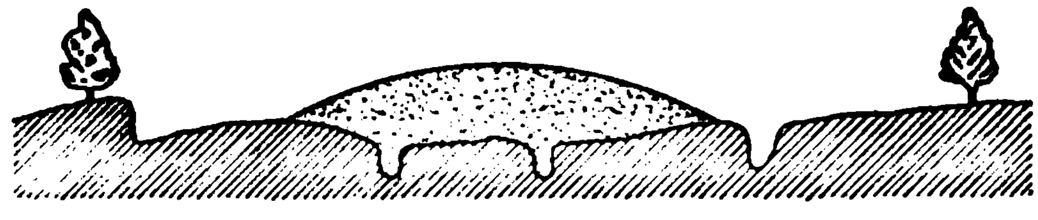

FIG. 112.—Cross-section of a Typical English Road a Hundred Years Ago, showing method of making repairs.

these previous beds of stone are called the bottoming of the road, and are of various thicknesses, according to the caprice of the maker and generally in proportion to the sum of money placed at his disposal. On some new roads made in Scotland in the summer of 1819, the thickness exceeded three feet.

"That which is properly called the road is then placed on the bottoming, by putting a large quantity of broken stone or gravel, generally a foot or eighteen inches thick, at once upon it, and from the careless way in which it is done the road is as open as a sieve to receive the water, which is retained in the trench." *

With respect to repairs, he says that there seemed to be "no other idea of mending a road than bringing a great quantity of material and shooting it on the ground."

John Loudon Macadam.

John Loudon Macadam was born on September 21, 1756, in Ayr, Scotland, where his father was a landed proprietor and founder of the first bank in the town. He was educated in the parish school, and is said to have shown an early inclination towards road construction by making a model of a road in the district. On the death of his father in 1770, he was sent to his uncle, William Macadam, a merchant in the city of New York, from whom he received his business training. During the American Revolutionary War he acted as an agent for the sale of prizes taken in battle, and on the declaration of peace, in 1783, he returned to Scotland, having remained loyal to the King of England.

After his return to Scotland he was for thirteen years a member of the Commission of Peace, and Deputy Lieutenant of the County. During the Napoleonic wars he raised a volunteer corps of artillery for the defense of the coast and was commissioned as a major.

During this period, as trustee on certain highways, he carried on experiments at his own expense, and in the face of great opposition he succeeded in improving the roads under his jurisdiction. The Highland Rebellion of 1745 had given an impetus to road building in Scotland, though these roads were chiefly for military purposes. Between 1760 and 1780 more than 600 Turnpike Acts were passed, but the roads actually built under this authority were constructed, as a rule, without system or technical knowledge.

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* "Remarks on the Present System of Road Making," etc., by John Loudon Macadam, 1820.

In 1798, Macadam moved to Bristol, England, and engaged in business connected with the victualing of the navy, but he spent much time in private travel about the kingdom in the investigation of roads and the various methods of construction and repair then in operation. By August, 1814, he had traveled 30,000 miles and had expended from his private purse over $25,000, but had gained experience that made him a recognized authority on road building and made his advice eagerly sought for by those having charge of roads, while his views were boldly expressed in print and before several parliamentary committees. The first recorded practical application of his knowledge, on a large scale, followed his election as a trustee of the Bristol Turnpike Trust. He found the roads of that district in a very bad condition, and on Jan. 16, 1816, he was appointed surveyor for the trust, in direct charge of construction and repairs. His salary was at first $2000 per year, and later $2500, and out of this sum he had to pay his traveling and other expenses, amounting to about $1000 per annum. The roads under his management aggregated 149 miles in length, but this was later increased to 178 miles. In June, 1817, he was enabled to report that none of the roads in the Bristol District were in bad condition; the cost of maintenance had largely decreased; the income had increased in proportion; a floating debt of $7000 had been paid off, and the principal debt had been reduced by $3650.

His work as surveyor to the Bristol Trust did not engage his whole time, and by 1819 he had been consulted by thirty-four different bodies of road commissioners, representing thirteen counties. In 1823 he had reported to seventy sets of commissioners in twenty-eight counties; and of these the roads in thirty-two trusts were being managed by Mr. Macadam and his sons according to the system devised by him, and the work done by men trained under him. Macadam received no compensation for this extra work other than his traveling expenses, and in the cases where the road trusts were very poor he did not receive his expenses.

The opposition to the Macadam system of road building was formidable at first, the chief objection being that the ramming

of the bed was unnatural and ineffective, and was damaging to the wheels of vehicles and to the feet of the horses, but the critics failed to remember that previous to the improvement of roads on the Macadam system the average life of a coach-horse was only three years.

In 1817 Macadam put down the first piece of macadamized road in London, by improving the approaches to Blackfriars and Westminster bridges. George IV. took a strong personal interest in the improvement of London streets, which fact induced Macadam to leave Bristol in 1823 and take up his residence within a few miles of London. In this same year he succeeded in getting an inquiry before a committee of the House of Commons as to his system, and he had constructed a full set of road-making implements, so that he could better explain the principles of his method. As a result, the merits of macadamized roads were publicly admitted and acknowledged, and Parliament voted, first, $10,000, and later raised this to $40,000, to compensate him for the money he had personally expended in bringing his system into practical and general use. He declined a baronetcy, but in 1827 he was appointed Surveyor-General to the Commissioners of Metropolitan Turnpike Roads, and his system was adopted throughout the kingdom. He died Nov. 26, 1836.

Thomas Telford.

Thomas Telford was born in the district of Eskdale, in Scotland, on August 9, 1757, and obtained the rudiments of his education in the parish school at Westerkirk. He learned the trade of a mason, then took up architecture in Edinburgh and later in London, and being a man of exceptional ability, he soon established himself as a leading engineer.

He became a bridge builder of note, making this his special study, but he also carried out many other engineering works, particularly that of locating and constructing new roads in all parts of Great Britain. His first undertaking as a road-maker on an extensive scale was in the Highlands of Scotland, where he was sent by the government in 1802 to report as to the best means of developing the resources of the country. He advised the opening out of the country by a complete

system of roads, so as to bring the interior parts into communication with the towns and the coast.

Under his direction, and by the aid of parliamentary grants amounting to nearly one million dollars, about 920 miles of road were scientifically laid out and constructed, and owing to the hilly and rugged nature of the country, works of considerable magnitude had to be undertaken, including 1117 bridges. This work was carried out in the course of eighteen years, under 120 contracts, and without recourse to a court of law in any one instance.

No work on roads is written to-day without an explanation of Macadam's and Telford's principles, so it will not be out of place to mention them and to discuss them in connection with the more extended knowledge and better appliances of the present day.

The following specifications show the difference in the methods of the inventors.

Tresaguet's method.

TRESAGUET'S METHOD, 1764 (Fig. 113).—"The bottom of the foundation is to be parallel to the surface of the road. The first bed or foundation is to be placed on edge and not on the flat, in the form of a rough pavement, and consolidated by beating with a large hammer; but is unnecessary that the stones should be even one with the other. The second bed is to be equally placed

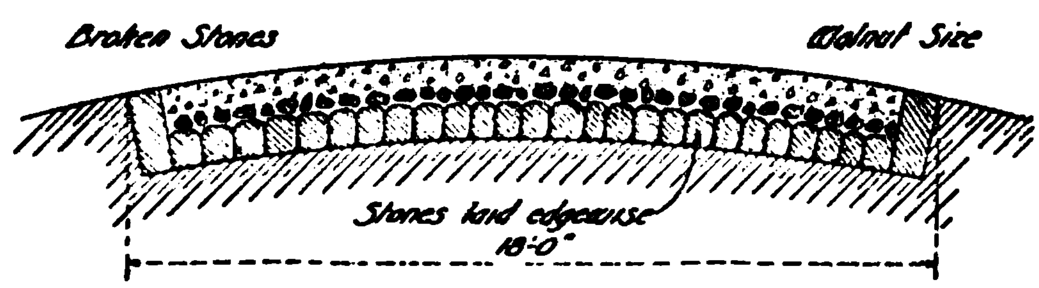


FIG. 113.—Cross-section of French Road Built by Tresaguet.

by hand, layer by layer, and beaten and broken coarsely with a large hammer, so that the stones may wedge together and no empty spaces remain. The last bed, three inches in thickness, is to be broken to about the size of a nut with a small hammer, or a sort of anvil, and thrown upon the road without a shovel to form the curved surface. Great attention must be given to choose the hardest stone for the last bed even if one is obliged to go to more distant quarries than which furnish the stone for the body of the road. The solidity of the road

depending on this latter bed, one cannot be too scrupulous as to the quality of the materials which are to be used for it."

Telford's method.

TELFORD'S METHOD, 1824 (Fig. 114).—"Upon the level bed prepared for the road materials a bottom course or layer of stones is to be set by hand in the form of a close, firm pavement. The stones set in the middle of the road are to be seven inches in depth; at nine feet from the center, five inches; at twelve feet from the center, four inches; and at fifteen feet from the center, three inches. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by hand with a light hammer, so that when the whole pavement is finished there shall be a convexity of four inches in the breadth of fifteen feet from the center.

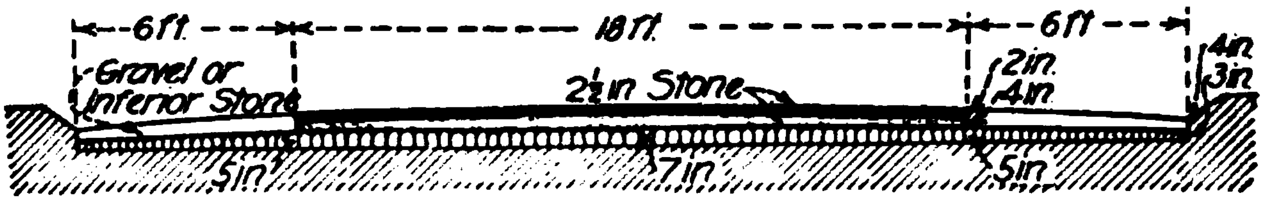


FIG. 114.—Telford's Shrewsbury and Holyhead Road.

"The middle eighteen feet of pavement is to be coated with hard stones to the depth of six inches. Four of these six inches to be first put on and worked in by carriages and horses; care being taken to rake in the ruts until the surface becomes firm and consolidated, after the remaining two inches are to be put on.

"The paved spaces on each side of the middle eighteen feet are to be coated with broken stones or well-cleaned gravel up to the footpath or other boundary of the road, so as to make the whole convexity of the road six inches from the center to the sides of it, and the whole of the materials are to be covered with a binding of an inch and a half of good gravel free from clay or earth."

MACADAM'S METHOD.—Macadam omitted the foundation of large stones, claiming that it was not only useless but injurious. He placed on the natural soil, a layer of stone broken into cubes of about one and a half inches in their greatest dimensions, and spread equally over the surface of the road, to a depth of ten or twelve inches.

No binding material was used, the stone being left to work in and unite by its own angles under the traffic. Macadam preferred the test of weight to that of measurement, and insisted that no stone should weigh more than six ounces, which is the weight of a cube of one and a half inches of hard compact limestone, and his

Macadam's method.

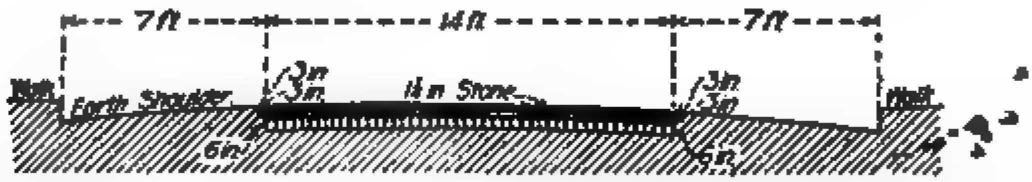


Fig. 115.—Modern Telford Road as Built in New Jersey.

overseers were provided with small scales and a six-ounce weight to test the larger stones. Macadam was the pioneer of scientific road construction in England, but he had been anticipated in the promulgation of the system of a regularly broken-stone covering by a Mr. Edgeworth, an Irish proprietor who wrote a treatise on roads, early in the nineteenth century. This contains the results of his experiments on the construction

Fig. 116.—Modern Telford Road in Excavation for Massachusetts State-Aid Roads.

of roads, with some useful rules, in which he advocated the breaking of the stone to a small size, and their equal distribution over the surface, also that the interstices should be filled with small gravel or sharp sand—a practice which, though condemned by Macadam, is now advocated by the best road-makers.

Modern telford and macadam.

Modern "telford" consists of a layer of stones eight inches thick, set by hand, on a natural-soil bed, properly graded. These are arranged and wedged as described by Telford. On this stone foundation, a layer of broken stone of a size not exceeding three inches is evenly spread and rolled and this surface is covered with

Laying Telford foundation on a gravel bed.
MASSACHUSETTS HIGHWAY COMMISSION.

FIG. 117.

(From Judson's "City Roads and Pavements.")

a layer of sand one-half inch thick, and the rolling continued. A layer of stone not larger than two inches diameter is then spread to the depth of four inches and rolled, followed as before with a layer of sand, which is also rolled. Finally, a coating of clean, sharp sand is applied, well watered, and the rolling continued until the surface becomes smooth.

Modern "macadam" pavements are constructed in the same manner but omitting the stone foundation, and the depth of the stone varies from four to twelve inches.

Defects of telford system.

The principal defects of the telford system are:

1. The large percentage of voids always left between the foundation stones, giving free access to water and thus defeating one of the main objects of the road covering.
2. The crushing of the smaller surface stones on the harder rock of the foundation by the traffic.
3. The high cost of construction due to the stone foundation.

Defects of macadam system.

The principal defects of the macadam system, when constructed as directed by Macadam is the looseness of the layer of broken stones. This cannot be impervious, because the interstices which compose a considerable portion of the bulk of loosely spread stones, cannot be reduced by any amount of rolling more than one-fourth, leaving a space that will be filled by the rising of the subsoil when moistened. The lower stones are then forced down by the weight of the traffic until the whole becomes a mass of mud and stones.

Advantages and defects of broken-stone pavements.

The advantages of broken-stone pavements are:

1. Good foot-hold for horses.
2. Easy traction when in good condition.
3. Moderate first cost.
4. Comparative noiselessness.

Defects common to all broken-stone roads are:

1. Muddy when wet and dusty when dry.
2. High cost of maintenance.
3. Difficulty in cleaning.

These defects prevent the use of broken stone for city streets, but when properly constructed and maintained, broken stone forms the most pleasant, the safest, and the most economic

surface for suburban streets and main country highways connecting centers of population, on which there is a moderate volume of travel. It is usually too expensive, however, for country roads other than the main ways.

The main difficulties in the construction of ideally perfect broken-stone roads lie in:

Difficulties in construction.

1. The quality of materials suitable for roadmaking found in different localities.

2. The conflicting properties possessed by these materials.

3. The following of methods of construction used and precedents established under entirely different conditions of climate and traffic. With methods of construction suitable to local conditions and with a thorough knowledge of the nature of the available materials under any given conditions satisfactory construction of broken-stone roads can be assured.

FIG. 118.—Cross-section of Roadway laid on Compact Earth and Made Solid and Permanent by Rolling.

The essentials requisite to the successful construction of broken-stone pavements are:

1. The removal from the roadbed of all vegetable or perishable matter.

Essentials for successful construction.

2. The removal of the natural soil to such a depth as may be necessary according to the character of the soil and the thickness of the intended covering.

3. Thorough sub-surface drainage wherever required.

4. The thorough compacting of the natural-soil bed.

5. The use of sand or gravel for the foundation.

6. The use of the best materials available either locally or imported from other places, according to the nature of the traffic.

7. The reduction of the voids in the mass of broken stone to the least possible amount, by properly proportioning and distribution of the different sizes of stone used.

8. The complete exclusion of clay or loam from the broken stone.

9. The use of sand or stone dust and screenings in quantity sufficient to fill the voids.

10. The thorough compacting of the broken stone with a roller of sufficient weight and suitable form.

Fig. 119.—Cross-section showing Wasteful use of Material.

Among the errors in broken-stone road construction which make the road very unsatisfactory and defective, are:

Errors in construction.

1. A permeable foundation in humid climates.

2. The use of excessively hard stones which cannot be consolidated by rolling.

3. The use of improper binding material, such as loam and clay.

4. An undue proportion of soft among hard stones.

5. Use of stones of too large size.

6. Use of stone from which the smaller fragments have been excluded by screening. Unscreened stones may be used for the lower course, but its use for the surface is unsatisfactory, as it wears unevenly, and owing to the differences in the size of the fragments, the variation in the proportions, and their unequal distribution in the mass, it is impossible to decrease the amount of voids.

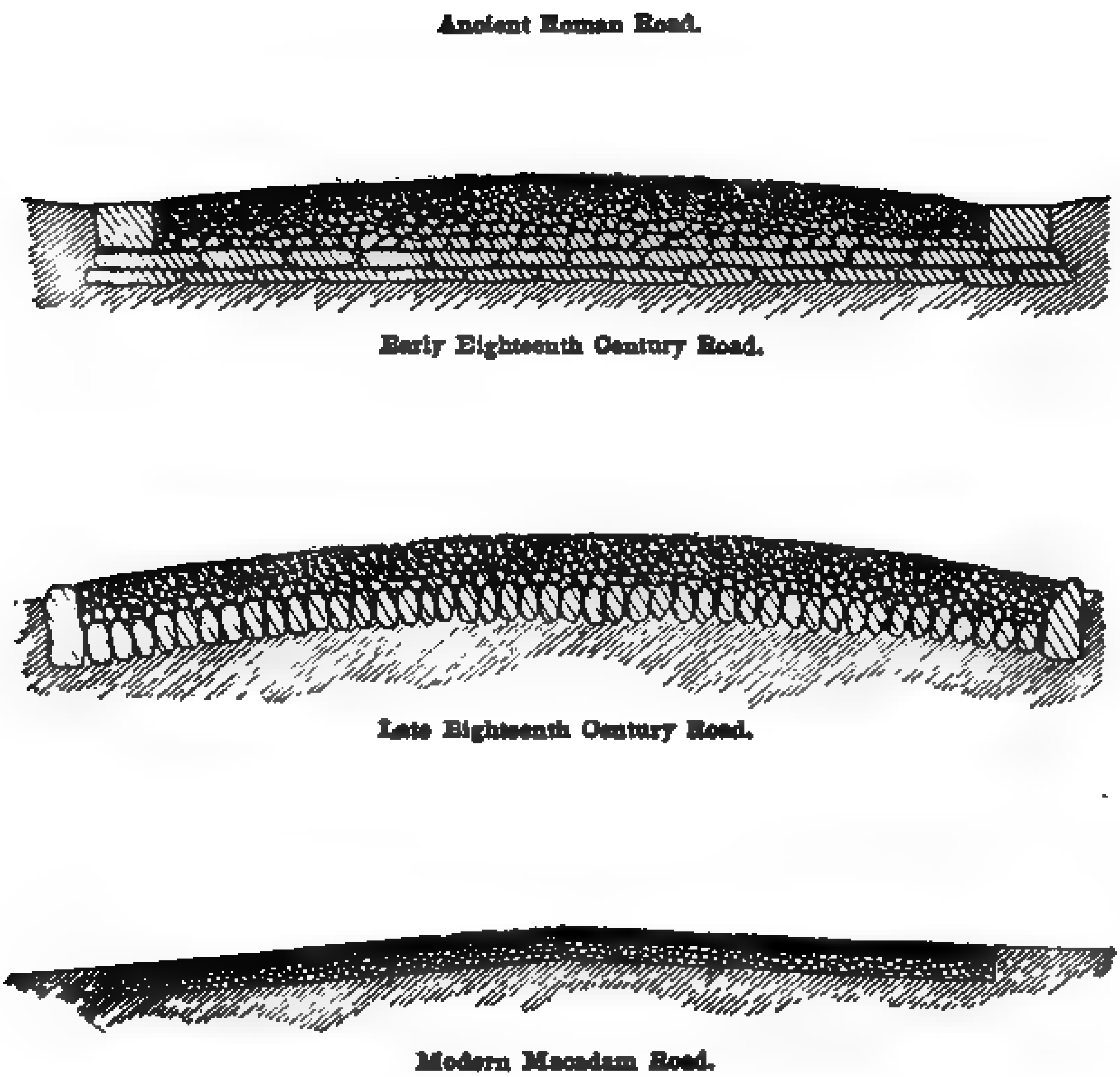
7. Laying the stone in layers, according to the size of the stone. The practice of building up a road with strata of screened stone assorted in different sizes and growing smaller towards the top is erroneous, as the smaller stone will sink to the bottom, and the larger stone will work to the surface, making the road porous and permitting the quick formation of ruts. The stone should be assorted by screening into the several sizes, then remixed in proper proportions to produce a mass containing the least possible amount of voids or a density as nearly equal to that of solid rock as is possible.

8. Covering the surface of the compacted stone with a layer of stone dust.

9. Use of an excessive quantity of binding material, or of water when rolling.

Materials. As stated in Chapter VI, the materials used for broken-stone roads must necessarily vary according to the locality, and on account of the many differences in climate and traffic it is evident that no single material is adaptable to all cases. As in practically every department of engineering, each problem requires individual solution according to local conditions, and to secure the best results in roadwork, the material selected and the method of construction employed must be adapted to the conditions under which the road is to be used and maintained. The specifications of Telford and Macadam were drawn up for use in a country with a moist climate. The water was useful in the construction of the road by aiding in the binding together of the material, but its removal was a necessity and made drainage of both the roadbed and the surface an important item in the maintenance of the road. In localities having little or no rain, drainage becomes relatively unimportant, and the methods for preservation of a well-bonded surface are of great consequence.

For ordinary country roads, experience has shown that the broken-stone way need not be more than from 12 to 15 feet wide, if suitable shoulders are built on each side. Twelve feet allows two vehicles to pass each other safely. Fifteen feet allows a little more space for comfort, particularly when



(From Judson's "*City Roads and Pavements*")

Fig. 120.—Relative Thickness of Ancient and Modern Roads.

motor vehicles are passing each other, and including the shoulders, this width will permit a team to stand beside the road while two vehicles are passing. If the stone is less than 12 feet wide there is a likelihood that the edges of the macadam will be sheared off by the wheels unless the shoulders are made of especially good material. Whatever may be the width of the stone, the shoulders should be firm enough to permit the occasional passage of wheels over them.

Dimensions of the macadam surface.

Until within comparatively recent years it has been almost universally the practice to build thick macadam roads. Roads less than 8 inches thick were rarely heard of, and often a thickness of at least 12 inches of macadam was thought to be necessary for good work.

The modern practice is to make the macadam surface as thin as possible, yet with sufficient body to stay in place, the theory being that the macadam is only a wearing surface. By lessening the thickness of the macadam much expense may be saved, since the foundation materials are usually less costly than broken stone. The macadam should be hard, smooth, and impervious to water. Much attention must be given to the foundation. It should be composed of porous material free from clay or loam, firm, and sufficiently strong to sustain any load likely to come upon the road at any time of the year.

In new work, where no macadam has been laid before, 3 inches of macadam after rolling is the least thickness which is practicable, and, except in unusual cases, a depth greater than 6 inches after rolling is rarely necessary if the foundation is suitable.

The ordinary macadam road is usually from 12 to 16 feet wide, with shoulders in addition 3 to 5 feet in width on each side of the broken stone. The thickness of the macadam is usually 6 inches at the center and 4 inches at the sides, or a uniform depth of 6 inches throughout. While the width and depth of the stone are often less than these dimensions, only in exceptional cases are they increased.

The actual construction of the road consists essentially of

three operations: (1) The preparation of the subgrade, or the natural-soil foundation on which the stone is placed; (2) Spreading of stone; (3) Rolling and finishing.

Subgrade.

The preparation of the subgrade to enable it to sustain the superstructure and the weights brought upon it requires the observance of certain precautions, the neglect of which will sooner or later result in the deterioration or possible destruction of the road covering. It is not enough

Fig. 121.—Cross-section of Sub-grade as Shaped by Grader.

that the roadway shall be graded with reasonable care. The surface upon which the broken stones are to be placed must be hard, smooth, and carefully crowned. If the foundation is not hard and firm the stones will be pressed into it by the roller and wasted. If not crowned, an unnecessary quantity of stone will be used.

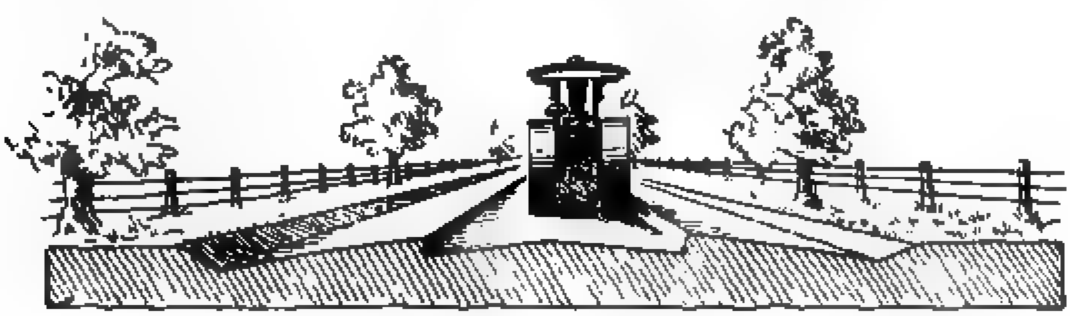


Fig. 122.—Shaping the Subgrade with Road Roller.

Primarily a well-drained, good foundation is a recognized necessity. This should be shaped as shown in Fig. 121. Most of the dirt to be moved in making the trench for the broken stone is ploughed and thrown out with an ordinary road grader, and the trimming up to the lines shown in Fig. 121 is then done by hand. The trench should be made as deep at the sides as

the stone is to be after rolling, the shoulders being made two or three inches higher than their final shape, to allow for their being compacted by the roller.

When the roadbed has been brought to shape, the trench is thoroughly rolled until it is hard and firm and shaped as shown in Fig. 122. Hollows and bumps are removed by cutting or filling, and the whole subgrade made hard, smooth and even, and of the same cross slope as that of the finished road. After the trench is made drains should be cut through the shoulders to the side ditches in all low places at intervals

FIG. 123.—Spreading the First Course.

of 50 feet on both sides. This will save many days' work in laying stone, as it will keep the subgrade dry when otherwise it would be flooded at every rain. These drains should be filled with the three-inch stone when the stone for the first course is spread; they then serve as permanent drains for the stone roadbed if water by any chance gets into it.

First course.

When the subgrade has been thoroughly rolled the first course of stone is spread. This ordinarily consists of stone broken to sizes varying from 2 to 3½ inches and need not be of especial hardness or toughness—ordinary good hard stone of any kind may be used.

The thickness of this stone, like every feature of the road, varies with local conditions. On good soil 4 inches loose is sufficient, but in some cases 5 inches and even 6 inches should be used. A course of over 6 inches cannot be thoroughly rolled and should never be used. Twelve inches of stone loose in the two courses is all that is ever necessary on a well-drained road, that is, two courses of 6 inches each without the dust.

It is often specified that stone for any course should not be dumped on the place where it is to be used; that is, that after each load of stone is dumped it should be raked or shoveled into place, moving each stone from the place it was dumped, and thus preventing unevenness in the road. While this is advantageous, it is sometimes impracticable and costly to have

FIG. 124.—Rolling the First Course.

this shoveling and raking done, especially on the second course of stone, and good results are obtained by taking care in raking down the stone from the pile. Rolling then levels all the stone to a uniform thickness, making a road smooth enough for all practical purposes. The screenings, however, must not be dumped directly on the road surface, but must be spread from piles or directly from wagons.

When 100 feet or more of stone is spread and shaped, rolling is commenced and is carried on until the stone is thoroughly compacted.

Second course.

The first course having been thoroughly rolled, the second course should be spread the same width as the first. This course should consist of the best material economically available; which means the material that for a fixed sum will produce the greatest road value, not for a year, but for twenty years or more.

The stone should be broken in size from ¾ to 2 inches, and be screened as closely as possible to these sizes. It should be spread to a depth of not less than 3 inches nor more than 5 inches in any case, varying with the hardness of the stone, etc., and the total depth of road desired. This course must be spread with the same care as the first course and rolled in the same manner until the stone is firmly in place and the whole is firm and even.

FIG. 125.—Rolling the Second Course.

Third course.

The road is then ready for the third or binder course, which should consist of stone screenings varying from dust to ¼-inch in size. It is usual to have this of the same material as the second course, though small gravel or sand can be used for binder for some rocks with good results. The dust should be spread with shovels from the wagons or from piles alongside the road, but never dumped directly on the stone surface. It should be applied with a quick, jerky motion so that a shovelful goes over a large area, until the second course of stone is entirely hidden and there is a uniform coat of about ½ of an inch over the whole surface of the stone. Then the road should be rolled as before until the dust is well pressed into the space between the stone and a coating left on the surface. Bare places as they appear should be covered with more screenings until the whole is firm and hard and none of the second course stone show.

The road should then be thoroughly sprinkled with water from an ordinary street sprinkler to wash the screenings into the voids in the stone, and when it flushes or rises to the surface it shows that the voids in the stone have been filled. A road is properly flushed when the steam roller following

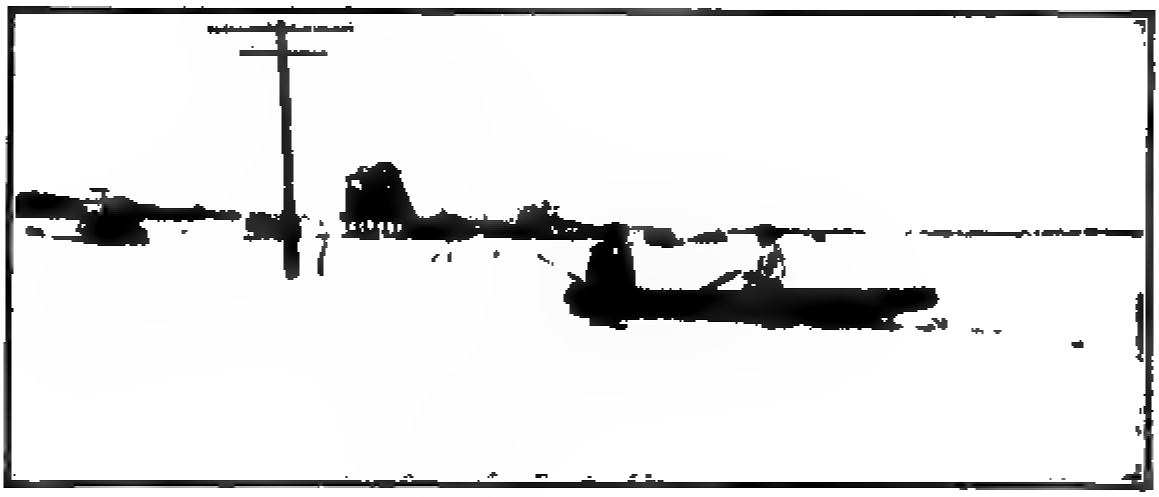
close behind the sprinkler has a wave of water continually going before the wheels. This flushing causes the dust to settle, and bare places that show again should be covered with more screenings and sprinkled and rolled until the whole is firm and hard, and uniformly covered with a thin coat of dust. Just enough dust should be applied to cover the stone

FIG. 126.—Rolling the Binder.

at all stages of the finishing. Too much dust soon ruts, travel becomes concentrated in these ruts, and water standing in them causes a soft place in the stone below and the ultimate destruction of what would otherwise have been an excellent road.

After a section of road has been flushed and finished it should be closed a day or two before permitting travel upon it; this gives the road an opportunity to dry out and harden and prevents the raveling and picking up of the road surface which sometimes occurs when a newly finished road is opened too soon and in too wet a condition.

a. Method of Construction, Showing Curb to Prevent Washing.



b. Road Under Water.

c. Completed Road.

FIG. 127.—Macadam Road Built through River Bottom (Auburn, Neb.).

When the operations outlined above are about finished a road machine with the blade set to the proper slope should be run carefully over the shoulders and all surplus dirt removed, and the slope from the center of the road to the ditches made smooth and uniform so that water falling on any part of the road surface is quickly carried into the ditches.

Trimming.

The broken-stone road of to-day is quite a different structure from the type of road built by Macadam, who used hand-broken stone that was practically uniform in size, laid in the road without the addition of a binder of stone dust or sand and left to be compacted by passing wheels. Improvements in methods of construction have reduced the thickness from the 36 inches of the Romans to the 18 inches of Telford, to the 12 and even the 6 inches of Macadam, to the 6 and in some cases the 4 inches of to-day; the chief factors being: (1) proper drainage and rolling of the earth foundation, (2) the use of machine-broken and screened stone with the screenings for a binder, (3) thorough consolidation with a steam roller; and it is safe to say that an economic road cannot be built unless all of these factors enter into its construction.

Efficient rolling is a matter of great importance; many roads coated with material of good quality suffer and become loose when the water in the binding has dried out. The condition to be aimed at is to solidify the coating with a suitable binding applied in small quantities by rolling so as to approximate the original bulk occupied by the material in the solid. All excess binding should be squeezed out by repeated passages of the roller and swept off. This produces a solid crust capable of resisting most effectually the action of ordinary wheel traffic and containing the least quantity of soluble matter to form mud in wet, and dust in dry, weather.

Rolling.

The non-professional reader may have wondered why a mass of broken stone, when sprinkled and rolled, finally becomes a solid pavement, impervious to water, acting in all respects like concrete, although no cement mortar has been used. That such a result could be obtained seems not to have occurred to anyone before the time of Tresaguet, and even he

did not trust to the broken stone alone to sustain loaded wagons, for he used an underpinning or "bottoming" of large paving stone. It was Macadam who, by omitting the bottoming, showed conclusively that broken stone possesses the property of knitting together, or becoming cemented under the rolling action of passing wheels, but it is doubtful if Macadam himself understood the philosophy of this cementing action.

What holds macadam roads together.

It is not the roller, that, by shaking and pounding a mass of loose, broken stones placed on a road, finally compresses the stones together until they are almost, if not quite, as compact as solid rock. In the first place, the roller does not compress the stone to its original volume, that is, it does not reduce the voids to zero; and secondly, a road is never bound when the rolling is finished, unless a binder has been added. The screenings or binding materials are essential, but there are various views as to their action. Mr. H. P. Gillette in a discussion of this cementing action,* says:

"A true explanation of the phenomenon seems to be found in a study of the sand on a seabeach.

"Where the waves break, the sand is firm and makes a very fair road itself, while a little farther back, beyond the reach of the waves, the sand is loose and yielding. The waves have evidently been the means of binding the sand.

"Each wave as it rushes up on to the beach carries in suspension an amount of fine sand that is precipitated upon the surface of the beach where the wave breaks and is washed down into the voids of the larger particles of sand, thus puddling or filling up all large interstices; but there is one more necessary condition to secure firmness and sustaining power—the sand must be moist. The fine capillary pores hold the water, or rather the water in the pores holds the sand together by virtue of its surface-tension, a well-known physical phenomenon; and it is this surface-tension or viscosity of water that binds the sand together and makes of the sand beach an excellent surface to walk or drive over. Strange as it may seem, dust and water, commonly considered the two greatest enemies of good roads, are, when in their proper places, the two

* "Economics of Road Construction," p. 21.

elements that prevent the disintegration of macadam. The writer conceives that macadam is first bound, not by cementing action, but by the surface-tension of water on the capillary voids of the screenings, and he offers the following facts as evidence of the truth of this theory.

1. A road built without screenings will not bind unless it is left long enough under the action of hoofs and wheels to produce screenings.
2. A road built with screenings will not bind if all the dust has been taken out of the screenings, leaving only the coarser particles, but will bind immediately upon the addition of the dust and water. The writer has tried this experiment under the direction of a "good roads expert" who had ordered all the dust to be screened out, under the mistaken idea that it would be injurious to leave it in; but, as stated, it was found impossible to bind the road until the dust was spread over its surface and washed into the voids.
3. A road will not bind until sprinkled, even after the screenings or binder have been added.
4. Time for iron-rust or other cementing action to take place is not necessary. A newly bound road, one that can be picked to pieces without evidence of any cementation, will uphold a heavy wagon, behaving exactly like an old road.
5. The screenings of a very hard rock like trap bind slowly, sometimes not at all, due to insufficiency of dust necessary to produce capillary voids; but upon addition of a little sand or road-sweepings, bind immediately. Conversely, the screenings of a soft rock, like limestone, rich in dust, bind quickly.
6. Hygroscopic rocks (those that condense moisture upon their surfaces), like limestone, furnish better screenings for binding and do not ravel as quickly in dry weather as siliceous or quartz-like rocks.
7. Long-continued drought causes macadam to ravel and finally go all to pieces, while it immediately knits together again after a rain.
8. Macadam in tunnels, where not sprinkled, soon ravels, as do likewise windswept roads that are kept free from sufficient dust and moisture.

"The writer is not to be understood as advocating the use of dust and water alone to produce binding, rolling being quite as important a factor, if a road is desired that will retain a smooth surface. Rolling in the first place so con-

solidates the stone that there is little chance for play or movement, while the screenings and water added render appreciable movement impossible.

"Sand and water, or screenings and water, though not a true mortar, serve the same purpose, as we have seen, and the less mortar in any masonry structure the more perfect and durable it is."

Steam rollers are made in different weights and used accord-

Fig. 128. – Steam Roller.

Steam rollers.

ing to the condition of the road to be treated, and the class of material employed for repairs. Consideration also must be given in regard to gas and water mains and other pipes under the roadway, which, in many instances, are quite near the surface, or have but a limited cover. The weight of rollers principally used are 12 to 15 tons; the latter is mostly employed in localities where the roadstones are hard and of good wearing quality. For good country roads a so-called "10-ton roller" is sufficiently heavy, as most of the culverts and many of the bridges are too weak to sustain, with safety, the heavier rollers. The prices of such rollers range from $2500 to $3500.

Breaking stone for road purposes was formerly done by hand,

but since the invention of the mechanical stone crusher the cost has been reduced from 50 to 200 per cent and the daily output has been increased by 50 per cent. In some European countries, however, hand-broken stone is still preferred on the ground that it is better broken and has sharper angles than that broken by the crusher, and in many districts the occupation affords employment for persons who would otherwise be thrown upon the public for support.

Breaking stone.

The main objections to machine-broken stone are:

1. Want of uniformity in size of stones.
2. The stone is frequently flaky with round edges, which is a very disadvantageous form for compacting.
3. Very tough stones have frequently to be passed several times through the machine before they are properly broken.
4. Very soft stone are crushed to powder.

There are two types of crushers now in common use: the "Oscillatory" (Fig. 129) and the "Gyratory" (Fig. 130). The former consists of a strong iron frame, near one end of which is a movable jaw, operated backward and forward a slight distance by means of a toggle-joint and an eccentric. As the jaw recedes, the size of the opening increases and the stone descends; as the jaw again approaches the frame, the stone is crushed, the size of the product being determined by the distance the jaw plates are from each other at the lower edge.

Stone crushers.

The second form consists of a solid conical iron shaft supported within a heavy iron mass shaped somewhat like an inverted bell. In the pattern shown in Fig. 130, an eccentric sleeve, driven by a removable steel gear, rotates around a stationary central shaft, crowding a lined crusher-head outwardly along horizontal lines, and producing the stroke which causes the stone to be crushed as it descends. It is claimed that this form has an advantage over the "oscillatory" in that no time is lost in crushing, and the power is uniform and continuous.

The arrangement of the plant for handling and crushing the stone is very important. It should be arranged so that the stone may be delivered from the quarry or from the field on a

FIG. 129.—Oscillatory Crusher.

The main frame (50), a solid piece, with front and rear inside ends planed for the seats of the stationary jaw plate (58) and the removable shims (75) (56) is the steel swing jaw, having a jaw seat planed for the jaw plate (55) The steel pitman (52) is lined with babbitt, and means of taking up the wear of bearing is effected by the tapered keys (74) and the bottom half box (54) The toggle bearings (62) are of steel, and are held in position by means of wedge blocks (63).

(Courtesy of The T. L. Smith Co)

FIG. 130.—Gyratory Crusher.

level with the mouth of the crusher, and thus save lifting the entire product and throwing it into the machine. The crushed stone should be elevated to bins or pockets, one for each size, so arranged as to discharge directly into the carts or wagons that haul it to the road. The bins should have a considerable capacity so as to prevent stoppage of the machine if the roads are too bad for hauling or if for any other reason the removal of the crushed stone is delayed. There should be ample room around the plant to prevent the interference of teams coming and going.

Stone-crushing plant.

Revolving screens made of steel plates perforated with holes are used in the crushing plant to separate the stone into the different sizes and to remove the tailings. Dust jackets are used in connection with the screens, to separate the dust from the crushed stones.

There are several kinds of portable plants which may be bought at prices ranging from $1600 to $2500, which are admirably adapted for country use. These plants include the stone crusher, engine, and boiler, portable bins, revolving screen, and an elevator to lift the stone after it is broken and to discharge it into the screen.

The outfits are mounted on wheels and may be moved from place to place at a comparatively small cost. Under ordinary conditions from $50 to $100 will pay the expense of shifting such a plant from its old location to a new location several miles distant.

Stone-distributing carts.

Stone distributing carts (Fig. 133*a*) are specially designed to distribute broken stone on roads. The bottom of the cart slopes downward to the back and the tail-board is hinged at its upper edge and is furnished with two adjusting chains by which the opening or swing of the lower edge is regulated. Steel wings are attached to the sides of the cart at the tail-board for the purpose of spreading the stone the full width between the wheels. The cart is tilted by a rack and pinion operated by the driver and may be fixed at any desired angle. As the stone flows from the rear of the cart it is leveled by a scraper attached to the bottom of the tail-board; this scraper is piv-

Unscreened tailings to be returned to crusher.
Screens and bins for various sized stones
Wagon loading crushed stone from bin
Crusher under platform
Cart dumping rock from quarry on to platform over crusher.

FIG. 131.—Crushing and Screening Rock.

oted at the center and can be adjusted so as to spread the stone to any required thickness and over any desired width equal to or less than the guage of the cart, and thicker on one side than the other.

Scarifiers.

Scarifiers (Fig. 134) are machines or mechanical devices used for picking or breaking up of broken-stone roads preparatory to the applying of new road material. There are two types; one fashioned in the form

Fig. 132.—Portable Crushing Plant.

of ploughs and harrows, and the other based on the principle of the rock drill or ore-stamping mill. They are drawn by horses or tractors. The shoe is usually reversible and adjustable, and provided with a sharp and blunt point, according to the class of work. When using scarifiers, it is essential to have the road thoroughly soaked with water.

Straight-edge.

The Straight-edge, or Road Level (Fig. 135) is used for obtaining the proper transverse form of roads. It consists of a horizontal bar having in the center of its length a plummet for ascertaining when the straight-edge is level. Adjustable gauges formed of upright pieces of wood marked off in inches are placed at every four feet.

Since water is always needed in rolling the macadam, a

FIG. 133*a*.—Stone Distributing Cart.

(Courtesy of Climax Road Machine Co.)

FIG. 133*b*.—Automatic Distributing Wagon.

watering cart or sprinkler should be provided. The road official cannot often afford to wait for rain. A cart with a capacity of from 450 to 600 gallons will be sufficient. Most of these carts are provided with extremely broad tires, so that the cart assists in

Water carts.

Fig. 134.—Scarifier.

consolidating the stone, instead of rutting it. Many communities are provided with one or more watering carts, so that it is often unnecessary to purchase a new one for road building.

Comparisons of average costs of roads in one locality with

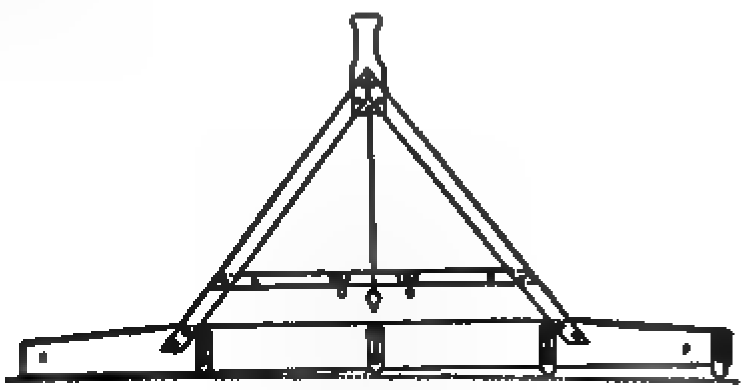


Fig. 135.—Straight-edge.

those in another are of little instructive value, for the reason that the condition in the two localities compared are never precisely similar, and but rarely even approximately alike. Particularly is this true of such details as earthwork and drainage. Even the costs of broken-stone surfacings, which at first thought

Cost of macadam surfaces.

(*Courtesy of the Buffalo Pitts Company*)

FIG. 136.—Traction Engine Drawing Train of Stone Carts.

might be considered to be comparable, one locality with another, often lead to wrong conclusions. There are too many factors which are dependent on local conditions. With this caution, certain cost data of macadam work alone are given below. The data are from the records of State work in Massachusetts and New Jersey. In each case the measurements and costs are of the stone in place and rolled, and the lengths and costs are estimated upon the basis of a roadway 15 feet in width. Tables X and XI relate to the macadam work alone and do not include the expenses of grading, drainage or any other incidental items, and Table XII gives the average of these items exclusive of macadam.

TABLE X

AVERAGE COSTS OF MACADAM WORK IN MASSACHUSETTS

Source	Depth of Stone at Center. Inches.	Depth of Stone at Sides. Inches.	Total Distance Built. Miles.	Cost per Mile. Dollars.	Cost per Square Yard. Dollars.	Cost per Ton (2000 Pounds). Dollars
Imported stone (trap rock)	6	4	8.25	5496	0.6245	1.956
	4	4	6.97	4746	0.5393	2.025
Local stone	6	4	21.74	3696	0.4201	1.396
	4	4	6.56	3459	0.3931	1.583

TABLE XI

AVERAGE COSTS OF MACADAM WORK IN NEW JERSEY *

Depth of Stone. Inches.	Total Distance Built. Miles.	Cost per Mile. Dollars.	Cost per Square Yard. Dollars.
4	6.441	2148	0.2422
5	1.772	3652	0.4150
6	7.129	5637	0.6299
8	21.748	6187	0.6958

* Report of the Commissioner of Public Roads of New Jersey for 1905.

TABLE XII

AVERAGES OF CONTRACT PRICES FOR THE SEVERAL CONSTRUCTION ITEMS, EXCLUSIVE OF MACADAM.—MASSACHUSETTS HIGHWAY COMMISSION

Excavation	per cubic yard	$0.4352
Borrow	"	0.5622
Ledge excavation	"	1.78
Cement concrete masonry	"	8.85 *
Shaping road for broken stone	per square yard	0.281
Vitrified 12-inch clay pipe, in place	per linear foot	0.7662
Vitrified 10-inch clay pipe, in place	"	0.6430
Vitrified 8-inch clay pipe, in place	"	0.5700
Vitrified 18-inch clay pipe, in place	"	1.57
12-inch iron water pipe, in place	"	2.20
18-inch iron water pipe, in place	"	3.75
Stone filling for V-drains, in place	per cubic yard	0.8271
Guard rail, in place	per linear foot	0.2776
Catch-basins, in place (including catch-basin frames and grates)	Each	35.74
Setting stone bounds	"	1.85

* This price does not include the cement or the steel reinforcement, which may be estimated at about $3 additional.

CHAPTER IX

ROADS IN MOUNTAINOUS DISTRICTS

PROBABLY the greater part of the roads in mountainous districts have been built for strictly utilitarian purposes; in the United States most of them have been built to meet a need arising in some way from the existence of mineral deposits. The prospector, with his tools, blankets, and simple food packed upon his burro, goes ahead; for him neither roads nor trails are necessary or specially desirable. He finds the mineral; the news gets abroad, and at once others flock in to the newly explored region. Then comes the trader with supplies, men to buy the mineral output, and miners to work the new finds. The freighter with his mule teams furnishes transportation, and for his use are built the first mountain roads. The first desideratum seems to be a route over which vehicles on four wheels can travel without tipping over. It is often so steep in places that wagons can only be pulled up with blocks and tackle, and descend with wheels rough locked and dragging a heavy log behind.

Evolution of mountain roads.

Next come roads to particular mines, toll roads, county and State roads, usually of such bad construction that it may be truthfully said that the money squandered in traveling over them would, in five years or less, build new ones intelligently located and properly constructed. Such roads would make available vast deposits of minerals now lying idle, furnishing new markets for labor, mining machinery, and farm products, and benefiting directly or indirectly every industrial and financial enterprise in the country.

But mountain roads must not be considered alone from an industrial standpoint—the inspiring, health-giving effects of mountain air and mountain scenery are universally conceded

FIG. 137.—The Mesa and Roosevelt Stage Road, Salt River Project, Arizona.

and for both those living in them, and those who come to them for business, pleasure, or health, the need for roads which can be traveled in safety and comfort is just as imperative as it is elsewhere. The sentiment which demands good roads is increasing steadily and will not halt at the foot of the mountains.

The location and construction of roads in mountainous countries present greater difficulties than in an ordinary undulating country. The most important consideration is grade. As stated in Chapter I for freight traffic the maximum grade admissible is 12 per cent. Four animals, together with the wagons used on a mountain road, are all that one driver can safely and properly handle on steep grades. When he uses two wagons, lead and trail, at every stop ascending he must hold both wagons by the brakes on the lead; in descending with heavy loads, he must control his wagons with brakes on both and when the road is icy he must control the descent by rough-locking one or more of his rear wheels. To do this, he attaches some rough device, like a piece of chain, or a short steel runner, grooved on the upper side to fit the tire and with projecting prongs on the lower, to the rear wheel, and a chain attached firmly to the center of the forward axle is then tightly fastened to this rough-lock. Thus secured, as the wagon descends the hill, the wheel remains rigid and the rough-lock plows into the surface of the road.

Grade.

Experience in heavy freighting has shown that wagons can be actually and satisfactorily controlled in all weathers on 12 per cent grades, but that they can not be thus controlled on steeper grades, and that where much heavy freighting has been attempted on steeper grades it has almost invariably been attended with terrible accidents. On a properly constructed dry road four animals, averaging 1300 pounds each in weight, will haul 6500 pounds, total weight, distributed between wagons and contents, up a 12 per cent grade, at the rate of about 1½ miles per hour. Descending, the four animals will haul all that a wagon can hold up, but in practice this amount rarely exceeds 16,000 pounds on a single wagon or

Fig. 138.—Ute Pass, Colorado.

Fig. 139.—Ouray and Silverton Toll Road, Colorado.

20,000 pounds on a lead and trail, and the average is probably about 10,000 pounds or 14,000 pounds.

Mountain roads are routes of travel between points of different altitudes and the most common, as well as the most serious, mistake made in their location is the attempt to cover this distance by too short a line. On a 12 per cent grade every pound of freight going up is elevated 12 feet for each 100 feet of horizontal distance traveled. On an 8 per cent grade it is elevated 12 feet in 150 feet of horizontal distance traveled, while on a 6 per cent grade it is elevated the same amount in 200 feet of horizontal distance; or, in other words, the distance required to get a 12 per cent grade must be increased one-half for an 8 per cent grade and doubled for a 6 per cent grade. The limit of load which a team can pull on any road is determined by the steepest place in that road, and it is putting it very moderately to say that a team will haul up 50 per cent more load in the same time between two given points on a road with an 8 per cent maximum than it could haul on one of similar surface with a 12 per cent maximum. A 12 per cent grade is admissible as a maximum and it is rare that a mountain road is built with a less maximum gradient, but it is also true that there are very few places where it was not feasible to secure a maximum under this, and the extra length that would be required is generally much less than might at first be supposed.

Besides the advantage in upfreighting, the 8 per cent road is vastly safer for both light driving and freighting; on passenger vehicles brakes, while desirable, are not essential to safety; with heavy loads, if the brake fails, there is a fair chance of escape for driver, team, and wagon. Such a road is not seriously damaged by rain and melting snows, which work much injury on steeper grades; damage from rough locking is enormously reduced, and as such practice can be to a great extent avoided, the time thus consumed is saved. Repair bills on wagons and harness are lessened, and the life of wagons is greatly prolonged. It is a pleasure to drive down an 8 per cent grade, but as gradients become steeper the sense of danger grows more and more keen. As a rule, a

lower gradient than 8 per cent means too long a route without commensurate advantage, while a higher means an unnecessary loss in the very purpose for which a road is required. The maximum adopted in the old Government pike crossing the Alleghenies was 7 per cent.

Next in importance to grade is location. The worst obstacle encountered on mountain roads is snow. The snow slide, or avalanche, comes sweeping down the mountain side, carrying along everything it meets and depositing its accumulations

Courtesy of The Literary Digest.

Fig. 140.—The Devil's Elbow, Isle of Wight.

Importance of location.

when the momentum is exhausted. The customary routes of these slides are generally quite apparent to the mountaineer, and in laying out a mountain road, they can be avoided by crossing to the farther side of the gulch and placing the line so high that the snow slide will always stop beneath it. If a snow slide covers a road it is rarely practicable to clear it for heavy traffic for months. The accumulation of ice, snow, rocks, trees, and débris of all kinds is so enormous, and the cost of removing it during the cold, short days of winter so excessive that a snow slide generally remains where it falls until warm w ather aids in its removal.

In roads designed for heavy traffic, it is the wisest economy to avoid snow slides at almost any cost.

Next to snow slides in obstructive effect are snowdrifts. These are due to air currents and act with remarkable uniformity from year to year. The places where these drifts accumulate in excessive amount can generally be located and avoided by careful attention. Deep ravines almost always catch snow. In a snow region it always pays to go around a point by a sidehill grade in preference to cutting through it.

Roads should always be located on slopes facing south and east in preference to slopes facing north and west, as they afford the sun greater power to settle and melt the snow.

Very steep sidehill slopes and hard rock increase the cost of road building, but it is often possible to avoid them to a greater or less extent. In fact, many of the problems in road location that at first seem impossible of practicable solution can be solved by observation and study. Thousands of miles of mountain railroad have been replaced at enormous cost, because of mistakes in original location, which more intelligent study would have avoided, and the same principle applies in road building.

Object of drainage.

In level regions roads are drained to protect their foundations; in the mountains they are drained principally to protect the surface. Water naturally runs off from a slope, and in doing so it must always leave more or less effect. Every mountain road must run through a valley or along a hillside. If in a valley, the surface should have a crown of at least 6 inches, with gutters and ditches and drains just as in properly constructed roads in a level region. In mountain roads on hillsides, the outside of the road must be the highest, with the view of conducting the water as quickly as possible towards the inside bank, where it should find a gutter to carry it to the nearest drain. This prevents the water from spilling over and washing away the outside bank, and also has a tendency to keep it from running down in the ruts and enlarging them. Another reason for keeping the outside of the road on hillside grades higher than

the inside is that there is always a tendency for the wheels of a heavily loaded wagon to slew toward the lower side, which becomes very serious when the road surface is slippery, and terrible accidents have resulted. Rain or melting snow always wears down some of the material from the inside bank. If the road surface slopes outward, this débris follows the drainage across the road, continually increasing the slope, sometimes very rapidly in cold weather; hence, the roadbed, for the protection both of the bed and the traffic, should be constructed and maintained with an inward slope of at least one-half inch to the foot. The inside gutter should empty into drains crossing the roadbed diagonally at suitable intervals, determined by the amount of drainage.

Necessity for proper side slope.

The importance of batter * in mountain road building is almost universally ignored. It is very common to see hill-side grades constructed with an insecure vertical cribbing constituting the outside of the roadbed; the inside bank cut as nearly vertical as possible, and three-quarters of the entire width of the road perhaps built of material filled in, the filling generally including all the trash available (boughs, sticks, boulders, etc.), with a covering of such material as the bank affords; and of insufficient width, to hold a wagon when the road is first built. The destructive forces of nature act vigorously on such a roadbed from the start. Ice and water rapidly wear down the inside bank, and the débris falls upon the roadbed; the trash foundation settles and the road sinks, sloping outward; water finds its way through this loose material and undermines the roadbed. The cribbing settles, rots, and soon disappears altogether and unless the road is practically rebuilt in a few years it grows more and more dangerous, and finally becomes absolutely impassable.

Cribbing is temporary in character, its use costly, and always to be avoided wherever practicable; when indispensable, it should have a batter not steeper than one horizontal to four vertical. Roads excavated in solid rock should have

* The side slope of a cut, embankment, or wall.

an inside batter of one horizontal to four vertical, which affords some latitude for projecting loads.

Cost, amount of traffic, safety, and comfort are the factors which must determine the width of a wagon road. Comfort and convenience are of course promoted by a double track; extensive traffic demands it; safety requires so much of it that teams can pass and never be caught unawares on a single track.

Width.

The proper width for double track and heavy teams is 16 feet, while it is possible for them to pass with extra caution on a 14-foot track on a straight road. For single track and greatest safety a desirable width is 12 feet, while 10 feet is generally safe, and an 8-foot roadbed can be driven over if the inside bank has sufficient batter, so that vehicles will not be crowded off.

Double tracks for turnouts should never be less than 75 feet long. These should be visible from each other and from every foot of the intervening distance. Before laying out a road, the maximum distance between turnouts should be determined from all the conditions, especial consideration being given to the amount of travel likely to occur at night, and this maximum should never be exceeded. Where this maximum is over 100 feet for turnouts adapted to heavy traffic, the road should be widened for short distances at intervening intervals, for light vehicles. A width of 12 feet will allow light vehicles to pass each other in an emergency and where the utmost economy must be observed, this extra width for a short turnout can often be secured by cutting into the bank. If this has been constructed with proper batter, the cutting makes the inside bank too steep at the turnout, but it is a choice of evils in the interest of greater convenience and safety to light traffic.

It is obvious that in sidehill grades excavated in easy ground, that portion of the road that is formed from the original material in place must for a time be more solid than the portion built out. It is consequently desirable on roads designed for very heavy traffic that all the wheels of heavily loaded wagons should rest upon the original solid formation.

Standard vehicles are either 4 feet 6 inches, or 5 feet between centers of tires. A very heavily loaded wagon can not be restricted to the same width of roadbed as light vehicles, but

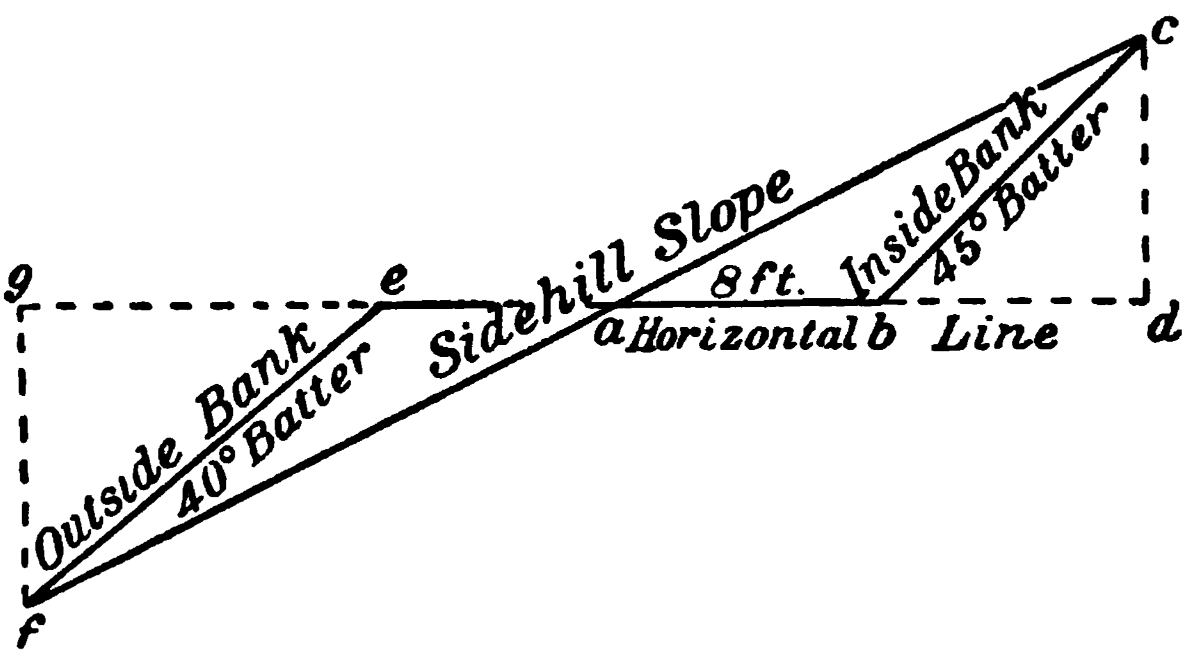


FIG. 141.

should be allowed a latitude of 8 feet for varying conditions of draft, road surface, etc.

TABLE XIII

WIDTHS OF ROADBED FOR VARIOUS SIDEHILL SLOPES, WITH AMOUNT OF MATERIAL EXCAVATED PER 100 FEET

Sidehill Slope (*cad*), Deg.	Width Made by Fill (*ea*), Feet.			Total Width (*eb*), Feet.			Excavation per 100 Feet, Cubic Yards.		
	8-ft. Cut.	6-ft. Cut.	5-ft. Cut.	8-ft. Cut.	6-ft. Cut.	5-ft. Cut.	8-ft. Cut.	6-ft. Cut.	5-ft. Cut.
5	7.89	5.92	4.93	15.89	11.92	9.93	11.26	6.33	4.40
10	7.83	5.87	4.89	15.83	11.87	9.89	25.33	14.25	9.97
15	7.72	5.79	4.83	15.72	11.79	9.83	43.41	24.41	16.96
20	7.52	5.64	4.70	15.52	11.64	9.70	67.41	37.89	26.33
25	7.29	5.47	4.56	15.29	11.47	9.56	103.41	58.15	40.41
30	6.87	5.15	4.30	14.87	11.15	9.30	161.78	91.0	63.19
35	5.94	4.45	3.71	13.94	10.45	8.71	276.59	155.59	108.06

A hillside composed of picking or plowing ground is rarely ever steeper than 35° and a grade formed by cutting 8 feet into such material makes an excellent road. The inside

8 feet of it is solid and adapted to the heavest traffic, and the balance, made by the fill, is sufficiently wide to allow lighter wagons to pass. The following table shows the total width of roadbeds for various sidehill slopes and the amount of material which must be excavated for each 100 feet of roadbed for 8-, 6- and 5-foot cuts into plowing or picking ground.

From these tables it will be seen that while there should be a cut of 8 feet into the bank for a double-track road, a cut of 5 feet will give a practical single-track road with only $\frac{11}{64}$ as much excavation, or that the double-track road requires more than two and one-half times as much excavation as a single track.

In sidehill grades in rock the conditions are very different.

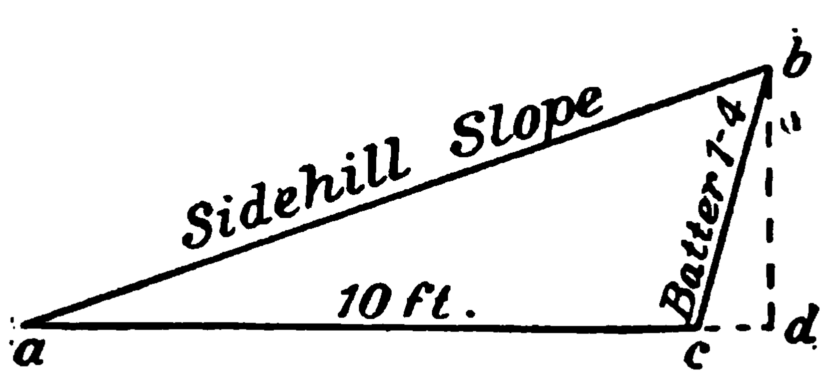


FIG. 142.

Rock excavations are made by blasting, which throws a large proportion of the rock down the hill, and consequently the material thus broken out can not be depended on with any certainty for fill. That which does remain available increases in bulk about 50 per cent.

When the natural surface of the rock is too steep to hold a fill it is often the better practice to cut the entire roadbed out of the solid rock as in Fig. 142. Such a roadbed is absolutely secure and in no danger of giving way without warning, through the failure of cribbing or retaining walls. For a single track this roadbed should be 10 feet wide, carefully protected on the outside by a guard log firmly bolted to the rock. The amount of excavation in solid rock on different hillside slopes to obtain such a roadbed is shown in the following table, which can be used for deeper cuts by using the rule that the amount of material varies as the square of the

depth of the cut. For instance, an 11-foot cut will require $\frac{121}{100}$ the excavation shown in the table; a 12-foot cut, $\frac{144}{100}$, etc.

Table XIV

AMOUNT OF EXCAVATION IN 10-FOOT CUT INTO SOLID ROCK

Sidehill Slope (*bad*). Degrees.	Excavation per 100 Feet. Cubic Yards.	Sidehill Slope (*bad*). Degrees.	Excavation per 100 Feet. Cubic Yards.
5	16.30	25	97.78
10	34.07	30	125.19
15	53.33	35	157.04
20	74.07	40	196.30

Curves.

The minimum curve allowable on mountain roads has the arc of a circle with a 30-foot radius for its outer edge. All sharp curves and their approaches from each direction should be level, a principle of great importance to the efficiency and safety of mountain roads.

Where a road zig-zags backward and forward up a hill in approximately parallel lines the turns are called switchbacks. They are expensive and very undesirable, and where possible, they should be avoided.

Wherever a bridge is approached by a curve its end should be flaring and the roadbed made wide and level, as curved approaches to bridge are very undesirable and should be avoided if practicable.

Slide rock.

In the mountains the hillside slopes are often covered with broken stone of various sizes, called "slide rock." This slide rock may be very coarse and the surface extremely ragged, when it is called "heavy slide"; it may be fine and bound together by soil, in which case it can be plowed or it may be fine and dry and run just like dry sand when disturbed, when it is called "fine slide rock." To construct a road in coarse slide a retaining wall is built on the outside of the grade, of large rocks weighing not less than 75 pounds each. The roadbed is then made as smooth as possible with the material at hand, and covered with fine slide. Coarse and

rough heavy slide may give the very best results when carefully handled, furnishing an absolutely solid, perfectly drained road foundation, unaffected by the elements, and requiring less outlay for repairs than any other variety of mountain road.

Probably the most difficult material which the mountain road builder encounters is fine slide rock; it appears to be so utterly unstable in every way that it seems impossible to obtain either definite or satisfactory results. It cannot be plowed or scraped and neither man nor animal can keep a footing in it, but fortunately, such patches are never very long, and while the process of making a road across it is tedious and expensive, it can always be successfully accomplished.

Corduroy.

In laying out mountain roads a spongy soil filled with water is often encountered which almost invariably proves to be shallow, with a substratum of good road material. This surface soil must be removed and a system of drainage adopted to keep surface water from running onto the roadbed. Occasionally corduroy is used to meet such conditions, but it is a very undesirable expedient, and is adopted only in extreme cases.

A thorough system of both cross and longitudinal drainage must be adopted to protect the corduroy from quickly rotting and to keep its foundation from settling unevenly.

Dressing.

As all mountains are made of rock, the soil with which they are in places covered being merely a product of rock decomposition and water concentration, a rock dressing prepared by nature can generally be found within convenient distance of a mountain road. A hard rock in angular fragments of two inches or less diameter makes an excellent road covering if some suitable fine material is put on top of it. Sometimes it is best to mix two kinds of rock, one hard and durable and the other disintegrating more rapidly through wear and chemical decomposition.

Most mountain roads at first require dressing only in stretches, and later for repairing holes and ruts and for maintaining a suitable inward slope. With a covering of 3 inches, 600 tons of rock dressing will completely cover a full mile of single-

track road, and on the average mountain road that amount would be sufficient for 2 miles.

As in all broken stone roads if the surface is to wear evenly, it should be homogeneous, and not built or repaired in spots with different kinds of materials; a clay road should not be patched with gravel nor a gravel road with clay. Holes or ruts should be filled with material of the same kind as constitutes the road surface. Detritus, resulting from traffic, which is washed by rains into the gutters, should not be placed back upon the surface, for it has lost its power of cementation; it should be thrown away and replaced by fresh material.

CHAPTER X

IMPROVEMENT AND MAINTENANCE OF COUNTRY ROADS

Reconstruction and Improvement

The reconstruction or improvement of existing roads is chiefly a question relating to the waste of effort and the saving of expense. Good roads reduce the tractive resistance of loads, and consequently the cost of moving the load.

The financial value of the benefits of a proposed improvement must be carefully estimated before any work is undertaken and this value must be ascertained for each portion of the road. To obtain this the following data are required:

1. The quantity and quality of the traffic using the road.
2. The cost of haulage.
3. Plan and profile of the road.
4. Character and cost of the proposed improvement.

The defects of existing roads are generally: (1) unnecessary ascents and descents; (2) unnecessary length; (3) imperfect surface; and the improvement may be divided into three branches:

Defects of existing roads.

1. Rectification of alignment and grades, consisting of the application of the principles laid down for the location, etc., of new roads. This includes straightening the road by eliminating unnecessary curves and bends, improving the grade by either avoiding or cutting down hills and embanking valleys, increasing the width where requisite, and rendering it uniform throughout (Fig. 13).

2. Drainage, consisting of the application of the principles laid down for the drainage of new roads, and in the construction of the necessary works.

3. Improvement of the surface, in the best possible manner.

Among the benefits of decreasing length and reducing grades are:

1. Saving in time.

2. Reduction in wear and tear of horses and equipment.

Benefits of improvements.

3. Saving the cost of maintenance of such unnecessary portion.

4. Reduction in the cost of haulage.

5. Saving by the return of the land previously occupied by the road to other and perhaps more renumerative uses.

6. Decrease in the working time of the horses and a slight increase in the load.

The benefits of improving the surface are a reduction in the cost of haulage and in wear and tear of horses and vehicles.

Clay soils can be improved only by means of thorough drainage.

Clay roads.

If sand, gravel, ashes, coal-dust, furnace-slag, or shells can be obtained, a coating of any one of them, 4 inches thick, well compacted by rolling, will form an improvement; if none of these materials can be obtained, the clay itself may be utilized by being burned, as described in Chapter VII.

In the maintenance of clay roads sods and turf should not be used to fill holes or ruts, as they soon decay and form soft mud; neither should the ruts be filled with field-stones, as they will not wear uniformly with the rest of the road, but will produce hard ridges. As all the sun and wind possible are required to keep the surface in a dry and hard condition, trees and close hedges should not be allowed within 200 feet of a clay road.

Sand roads.

In the improvement of sand roads the aim is to make the wheelway as narrow and well-defined as possible, so as to have all the vehicles run in the same track. An abundant growth of vegetation should be encouraged on each side of the wheelway, to prevent as far as possible the shearing of the sand. Ditching beyond a slight depth to carry away the rain-water is not desirable, for it tends to hasten the drying of the sands, which is to be

avoided. Where possible the roads should be overhung with trees, the leaves and twigs of which catching on the wheelway will serve still further to diminish the effect of the wheels in moving the sands about. If clay can be obtained, a coating 6 inches thick will be found a most effective and economical improvement. A coating of 4 inches of loose straw will in a few days' travel grind into the sand and become as hard and firm as a dry clay road.

Maintenance and Repairs

Proper *maintenance* is as important as good construction. This consists in keeping the roadway, as nearly as practicable, in the same condition as it was when originally made; the *repair* of a roadway is the work rendered necessary to bring it up to its original condition after it has become deteriorated by neglect to maintain it. There is a wide distinction between the two operations; the former keeps the road always in good condition while the latter makes it so only occasionally.

Necessity for maintenance.

No matter how well a road may be made, or how carefully the materials used have been inspected, it will soon show defects which it is almost impossible to guard against, such as variableness in the quality of the material, and slighting on the part of the workmen. Moreover, every material, whether natural or artificial, is continually undergoing a process of deterioration by the action of the elements. The materials employed for pavements are not only subjected to the destroying action of the elements, but also to abrasion and concussion, which by themselves are powerful destroying agents.

The essential requisite to the preservation of a good surface is eternal vigilance. If a depression appears in consequence of settlement, defective material, or other causes, it must be at once eliminated; if not, it will be quickly deepened and enlarged by each succeeding vehicle, and will thus become an obstacle to safe traveling.

Good maintenance comprises:

1. Constant attention to repair the damages made by traffic and the elements. The character and quantity of these re-

(*From Good Roads Magazine.*)

FIG. 143.—Section of Country Road before Improvement.

(*From Good Roads Magazine.*)

FIG. 144.—Section of same Road after Improvement.

pairs will vary with the character of the pavement and the manner of its construction. With granite blocks laid on a concrete foundation they will be the least; with broken stone they will be the greatest; the other materials, as wood, asphalt, and brick, lying between.

2. Cleaning, i.e., removing the detritus caused by wear, horse-droppings, and other refuse. (See Chapter XIX).

(From Good Roads Magazine.)

Fig. 145.—Section of same Road showing effects of Travel, resulting from improper Maintenance.

3. Laying the dust. (See Chapter XI.)

The most obvious feature in road maintenance is the application of new materials, but the prevention of avoidable wear, by keeping the surface and the body of the road in good condition, is hardly less important; and the removal of the materials from the road after they are worn to detritus, the care of the surface, and attention to drainage, are essential parts of a good system of maintenance. Experience proves that a road with sufficient strength, good surface, and thorough drainage can be kept in first-rate order with a much smaller quantity of materials than an inferior, ill-kept road

requires, and though a greater amount of manual labor may be necessary, a good road, on the whole, is generally more cheaply maintained than a bad one, especially when there is any considerable amount of traffic.

There are three principal systems of maintaining pavements:

Systems of maintenance.

1. By contract, at a fixed price per square yard per annum for a fixed period. This method is used for asphalt pavements in both the United States and Europe and for wood pavements in Europe, but rarely in America. It has the advantage of having someone admittedly responsible for the condition of the pavement, but it is the most costly system and there is always difficulty in determining the exact condition of the pavement at the expiration of the contract.

2. By independent contracts for the labor and materials, the tools and supervision being furnished by the city.

3. By men in the employ of the city. This is the most extensively used and most satisfactory system.

Maintenance of country roads.

As soon as a country highway is finished and opened to traffic a system of maintenance must be instituted. No style of construction is sufficiently permanent to admit of the road being left to take care of itself. Whether built of earth or stone, it will eventually wear into ruts and holes, the time depending upon the quality of the material, the form of construction and the amount of traffic. The chief object in the maintenance of an earth road is to get rid of the water as quickly and as fully as possible. In maintenance, as in construction, water is the great enemy of good roads. The secret of success in maintenance is to keep the surface smooth and the side ditches open. There are three systems in vogue: (1) By contract with private parties; (2) By personal service; (3) By men permanently employed for the purpose by the community.

1. The contract system is unsatisfactory, owing to the difficulty of getting a proper observance of the terms of the contract from the contractor or his employers.

2. The personal-service or labor-tax system is not applicable to the maintenance of improved roads, nor, in fact, to any

class of roads; it is unsound in principle, unjust on its operation, wasteful in its practice, and unsatisfactory in its results.

3. The system of permanently employing men for the purpose by the community has been adopted by France, Germany, and nearly all European countries and by the New York State Highway Commission, and has many advantages. The men so employed become familiar with the peculiarities of their sections and with the best way to deal with them, and good men soon learn to take an interest in the road which it is their business to keep in order.

The maintenance, or keeping of the road in proper order, consists of:

1. Removal or prevention of the detritus either in the form of dust or mud, and removal of the horse-droppings and other rubbish.

2. Filling of ruts or depressions.

3. Cleaning out of the ditches, catch-basins, and water-courses.

4. Keeping down the dust in dry weather. The dust produced by the disintegrating action of the weather and the friction of the traffic renders the road heavy for traffic and annoys passengers and horses.

Errors in maintenance.

The errors commonly committed in the maintenance of broken-stone roads are:

1. The unskilled application of materials.
2. Use of improper and unsuitable materials.
3. Neglect of repairs.
4. Insufficient and unskillful manual labor.

Well-made roads are frequently allowed to go to ruin through these wrongful methods of maintenance, requiring at some period that the neglect be made good at one time, instead of the work being spread out in proper maintenance over a period of years.

Cost of maintenance.

The cost of maintenance varies widely, depending principally upon the degree of perfection with which the road was originally constructed, and is largely influenced by the class of labor employed in maintenance.

The factors of cost of maintenance are:

1. The quantity of material that will be required to replace

the annual wear caused by traffic and the weather, and removed in the form of mud and dust, depending upon:

a. Width of road.
b. Nature of foundation, drainage, and thickness of crust.
c. Situation of the road.
d. Quality of the stone to be applied.

2. Cost of the material procured either by contract or by day labor under the supervision of the authorities, this depending upon:

a. Cost of quarrying.
b. Cost of breaking.
c. Cost of hauling from quarry to roadside.
d. Cost of stacking at the roadside.
e. Cost of loosening the stones in the heaps. A considerable item in frosty weather or when the stones have lain for some time.
f. Cost of hauling stones from depots to the portion of the road where they are to be used.
g. Cost of preparing the road-surface to receive the stone.
h. Cost of spreading the stone.

3. Cost of compacting the stone.
4. Cost of cleaning and scraping.
5. Cost of cleaning up the side of the road, ditches, etc., and keeping open watercourses, depending upon the frequency with which it will have to be done, usually three times a year is sufficient.
6. Cost of dust prevention.

To these items must be added a certain sum per mile for repair and replacing of tools, etc., and about 5 per cent on the total cost to cover the administrative charges.

Combining these factors in the following manner will give the probable cost of maintenance per mile of a given road.*

* Byrne, "Highway Construction," p. 668.

Let N = average number of cubic yards of stone spread per mile;
A = cost per cubic yard of stone in depots;
L = cost of preparing road-surface and spreading stone;
R = cost per cubic yard of rolling;
C = average number of times sides will require cleaning;
c = cost of cleaning sides, etc., per mile;
S = average number of times road will require cleaning;
s = cost of cleaning per mile;
W = average number of times road will require sprinkling;
w = cost of sprinkling per mile;
D = annual depreciation and renewal of hand tools;
I = cost of administration, say 5 per cent of total cost;
X = cost of maintenance per mile per annum.

Then

$$X = N(A + L + R) + Cc + Ss + Ww + D + I.$$

If stone is quarried by day's labor, its cost will be

$$A = q + b + h + p,$$

in which q = cost of quarrying;
b = cost of breaking;
h = cost of hauling;
p = cost of stacking.

Where funds have been provided for road improvements, efforts are usually directed toward building as much road as possible, while the matter of maintenance is entirely overlooked, and no funds are provided for needed repairs. The fact that no great inconvenience or damage arises from a slight depression in the road surface, or from a few loose stones, occasions neglect, and the condition of the road is allowed to become gradually worse. When the surface becomes, in time, so rough as to be a public nuisance, it is found that the cost of restoring the road is considerable; moreover the roughness of the road in the meantime has caused a "wear and tear"

to wagons, carriages, horses, etc., which is, in the aggregate, of considerable importance.

This neglect of repairs to public roads is very poor economy. It would be a remarkably well-constructed road that would not show some defects soon after it began to be extensively used. With the greatest possible care an earth roadbed cannot be made strictly uniform as to solidity, and heavy loads passing over the crust formed by the stones will press some of the stones into soft places in the earth bed, and this in time will cause a defect on the surface of the road. A very slight depression will at first appear, which may be detected only after a rain (by the water which will remain for some time in the depression). If this depression is permitted to remain it will soon become deeper and broader. As the wagon wheels go in and out of it they grind out the stone softened by water, and cut down the sides, so that what was at first a slight depression soon becomes a hole. Such neglect causes subsequent repair to be expensive.

Some of the causes which make repairing necessary, and which should be avoided or removed as far as possible are:

Causes which make repairs necessary.

1. Defective construction of earth bed.
2. Failure to cut off under-ground water by drainage.
3. Rain or storm water permitted to lie in pools along the roadsides or in side ditches which do not carry the water from the road.
4. The side slope being insufficient to carry the storm water from the road to the side ditches.
5. The longitudinal grade of the road being greater than the slope from center to sides.
6. The formation of ruts.
7. Raveling, or picking up loose stone.
8. Surface stone not of proper quality and not uniform.
9. Roadbed not sufficiently compacted.
10. Accumulation of trash or rubbish on the road.

When the road reaches the condition where restoration is necessary the work should be done in sections as large as convenient. The periods at which the restoring or recoat-

ing of a broken-stone road will be required depend upon the quantity of the traffic, and vary from one to five or more years.

Repair.

The methods practiced for recoating are: (1) the surface is cleaned from mud and dirt and the new stone spread over it; sprinkled and rolled in the same manner as a new construction; (2) the surface is "scarified," or loosened or broken up by picking or ploughing, before spreading the new stones. The object of this is to enable the new stones to become more completely incorporated with the old material.

For the proper care of the roadway, an adequate number of skilled laborers are necessary. This labor should be permanently employed by the community, and should be under the direct orders and supervision of the engineer in charge of the road. The force should consist of the engineer in charge, assistant engineers or inspectors, chief foreman, foremen and laborers.

The following instructions to Roadmen* will be found useful:

Instructions to roadmen.

"1. Never allow a hollow, a rut, or a puddle to remain on a road, but fill it up at once with chips from the stone-heap.

2. Always use chips for patching, and for all repairs during the summer months.

3. Never put fresh stones on the road if by cross-picking and a thorough use of the rake the surface can be made smooth and kept at the proper strength and section.

4. Remember that the rake is the most useful tool in your collection, and that it should be kept close at hand the whole year round.

5. Do not spread large patches of stone over the whole width of the road, but coat the middle or horse track first, and when this has worn in, coat each of the sides in turn.

6. Always arrange that the bulk of the stones may be laid down before Christmas.

7. In moderately dry weather and on hard roads, always pick up the old surface into ridges six inches apart, and remove all large and projecting stones before applying a new coating.

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* Road Improvement Association, London, England.

8. Never spread stones more than one stone deep, but add a second layer when the first has worn in, if one coat be not enough.

9. Use a steel-pronged fork to load the barrels at the stone-heap, so that the siftings may be available for "binding" and for summer repairs.

10. Never shoot stones on the road, and crack them where they lie, or a smooth surface will be out of question.

11. Go over the whole of the new coating every day or two with the rake, and never leave the stones in ridges.

12. Remove all large stones, blocks of wood, and other obstructions (used for diverting the traffic) at nightfall, or the consequences may be serious.

13. Never put a stone upon the road for repairing purposes that will not pass freely in every direction through a 2-inch ring, and remember that still smaller stones should be used for patching and for all slight repairs.

14. Recollect that hard stone should be broken to a finer gauge than soft, but that the 2-inch gauge is the largest that should be employed under any circumstances where no steam roller is employed.

15. Never be without your ring-gauge. It should be to the roadman what the compass is to the mariner.

16. If you have no ring-gauge, remember Macadam's advice that any stone you cannot put easily into your mouth should be broken smaller.

17. Use chips, if possible, for binding newly laid stones together, and remember that road-sweepings, horse-droppings, sods of grass, and other rubbish, when used for this purpose, will ruin the best road ever constructed.

18. Remember that water-worn or rounded stones should never be used upon steep gradients, or they will fail to bind together.

19. Never allow dust or mud to lie on the surface of the road, for either of these will double the cost of maintenance.

20. Recollect that dust becomes mud at the first shower, and that mud forms a wet blanket which will keep a road in a filthy condition for weeks at a time, instead of allowing it to dry in a few hours.

21. See that all sweepings and scrapings are put into heaps and carted away immediately.

22. Remember that the middle of the road should always be a

little higher than the sides, so that the rain may run into the side gutters at once.

23. Never allow the water-tables, gutters, and ditches, to clog up, but keep them clear the whole year through.

24. Always be upon your road in wet weather, and at once fill up with "chips" any hollows or ruts where the rain may lie.

25. When the main coatings of stone have worn in, go over the whole road, and, gathering together all the loose stones, return them to the stone-heap for use in the winter to follow; for loose stones are a source of danger and annoyance and should never be allowed to lie on any road."

Season for repairs.

The proper season for laying the bulk of the fresh materials is in the autumn and early winter. The precise time at which it can be begun will depend on the climate, weather, subsoil and the nature of the material. As soon as the surface of the road softens from the wet, patching of hollows, or wheel tracks, and channels worn by water, should be commenced, the mud having been previously removed where necessary. The greater part of the new materials should be put on before the end of the year, so that they may be at least partially worked in before winter, when they are most required in the road, and before severe frost comes. Unconsolidated materials are more annoying to the traffic in frosty weather, and there is waste by the stones being crushed and scattered instead of being incorporated in the road. Stones laid late in the winter seldom consolidate thoroughly, and those laid in the spring hardly set at all, but work loose in the dry weather, if they are not of a binding nature. If a road from any cause shows weakness in the spring, and requires stoning, everything must be done to aid consolidation, and great attention to the newly laid materials will be required. All stones which do not bind must be raked off as the season advances and there is no longer any prospect of their working in.

The autumn work on roads is generally commenced after harvest, as the additional men which are required are then more easily to be had. Cleaning up the sides cannot be well done in dry weather, but the constant laborers should take advantage of suitable moist weather to get forward with it, so that the water-tables may be cleared, the outlets to the side-

ditches opened, and the sod bordering trimmed before the wet weather sets in. If the manual labor be allowed to get behindhand in the autumn, there is often little chance of roads recovering it until the winter is over. Scraping is very necessary as soon as rainy weather commences, to get rid of the mud which then forms on the surface from the effects of the wear in the summer. As soon as the cleaning up of the sides is finished, and the scraping is well forward, the laying of materials

FIG. 146.—A Well-kept Country Road.

in small patches should begin. The first patches should be laid in places naturally damp, and when the road generally begins to soften from the wet weather, spreading materials and scraping will take up all the constant laborers' time, and usually requires casual labor besides until the middle of December, or even later. In the beginning of the year, after the great bulk of materials has been spread, less labor is necessary; only small patches to make good weak places which have shown themselves during the winter remain to be laid, and scraping is hindered by frost, and by the consolidated materials

about the road. As the spring advances more scraping will be required in damp weather, and in dry weather the stones which have not worked in will require the roadman's attention, and must be raked off if they will not set. The spring and early summer is the best season for cleaning out side-ditches which are not too wet. The stuff is moved easier when still moist, and it is well to get forward with work of this sort in the spring, and not to leave it till the autumn, when there is so much other work to be done.

CHAPTER XI

THE CONTROL AND PREVENTION OF ROAD DUST *

On wood, asphalt, stone, and brick pavements, the wear is so slow as to be practically negligible, and dust arising from any of these surfaces is produced by extraneous matter brought to the road in various ways from outside sources. But in the case of macadamized roads one of the most important problems that has yet been forced to the attention of road engineers and municipal officials is the suppression or prevention of dust arising from the road itself. There is hardly a section of the country in which this problem has not had the consideration of local officials, and the lack of information as to how to overcome it has resulted in many cases of transforming the "dust nuisance" into a mud or slime nuisance. This is especially so in rural districts where many officials have purchased oil without proper knowledge of its ingredients and its adaptability for use on the roadways of their districts, and have spread the oil broadcast over the highways, transforming them into slippery mires and making them unsafe for traffic of any kind.

Importance of dust prevention.

The "dust nuisance" is not, however, so much the result of the natural formation of dust by ordinary and reasonable traffic, as it is of the use of automobiles, the wheels of which draw out and throw into the air the particles that would otherwise fill the crevices and act as a bond between the broken stones of the macadam construction.†

Dust has always been a feature of broken-stone roads, being at the same time the result of use and a check upon excessive

* The best general treatise on this subject is "Road Preservation and Dust Prevention," by William Pierson Judson, from which much of the data of this chapter has been drawn.

† See Appendix III, "Concerning the Wear of Roads by Automobiles."

wear. Whenever the surface becomes free from dust, by wind effect or otherwise, it has been necessary to spread a thin layer of sand or screenings, or other fine material, as a protection to the stone fragments forming the road, and to prevent them from "raveling" or losing their bond. When these stones or the screenings forming the protective layer, or both, consist of limestone, the resulting impalpable dust is most objectionable to people driving upon the road and even more so to those living along it. When this limestone dust is wet, the resulting mud is the most slippery and dangerous for rubber-tired wheels, causing more side-slip than any other material used for roads.

Value and effects of road dust.

In 1905, when automobiles became common, the raising and scattering of road-dust increased greatly, and in the summer of 1906, when their use greatly increased both in Europe and in the United States, the subject at once became acute, and road-builders everywhere found that a new condition had suddenly developed, particularly on those macadam roads radiating from the cities where automobiles were most used. They found that the preservation of the roads demanded a better and more enduring surface, and one that will neither require nor produce the loose surface layer which had heretofore been a necessary feature.

Effects of automobile traffic.

In the Minutes of Proceedings of the Institution of Civil Engineers (London) for September, 1906, it is said:

"Experience has proved that the broad pneumatic tires of heavy motor-cars at high speed draw out the small particles which bind the material of a macadamized road. On the main roads* more than half the traffic is of motor-cars, which may reasonably be expected to become a more and more popular means of travel, to which the roads must now be adapted by introducing into them some material which would make them dustless; for which purpose, tar, or some tar derivative, is the only remedy now in sight. Motors have come to stay,

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* Of England.

Before Treatment.

(*Courtesy of Standard Oil Company.*)

After Treatment.

FIG. 147.—The Dust Nuisance and Its Abolition.

and the road-builders mean to make the roads fit to carry them."

That this condition equally concerns the road-builders of the United States is shown in the 1907 report of Logan W. Page, Director of the U. S. Office of Public Roads, in which he says:

"In recent years perhaps the most important and certainly the most difficult problem which has engaged the attention of highway engineers is the prevention of dust. Until the general introduction of motor vehicles, dust was considered as neither more nor less than a nuisance. The problem has now, however, assumed a more serious aspect. The existence of our macadam roads depends upon the retention of the road-dust formed by the wearing of the surface. But the action of rubber-tired motor-cars moving at high speed soon strips the macadam road of all fine material, the result being that the road soon disintegrates. . . . This is a subject which should engage the earnest attention of the National Government at once. No matter how important we may deem the building of good roads, we cannot but consider it even more important to preserve those which have already been constructed."

James Owen, M. Am. Soc. C.E., one of the most experienced of American road engineers, in a paper on "Highway Construction," before the 1906 meeting of the American Society of Municipal Improvements, said:

"Every system of road construction should be immediately supplemented by a maintenance organization, as in time the construction department disappears, but the maintenance department is permanent, and is the vital point in the future road-development of the country. . . . The automobile is demanding attention from engineers as to whether there should not be new means and methods for road maintenance."

Similar statements of motor-car effects, made by government commissioners, civil authorities, engineers, and in periodicals, all tend to show the dangers of road dust and the importance of its prevention.

The demand for relief comes not only from recognized

(*Courtesy of The Barrett Mfg. Co.*)

FIG. 148.—Beacon St., Newton Center, Mass. Built with Tarvia X, 1908. (Photo 1909, March.)

authorities and from the road users, but also from the property owners who live along the roads, and pay for them, and who find that the former dust to which they had objected has become an hundred-fold worse and not to be endured; some country residences which have long been desirable and valuable, have suddenly become neither tenantable nor salable, and others have been sold for half their cost because of the dust from adjacent roads. In Massachusetts passing motor-cars have even thrown up fragments of road-stones into the windows of houses.

Necessity for dust prevention.

The situation is well stated in the following quotation from the 1907 report of the Massachusetts Highway Commission, which has built and maintains the main parts of one of the finest road systems in the United States:

"Perhaps the most important discovery of the year is the extraordinarily destructive effects upon stone roads of the large number of swiftly moving automobiles. Practically all the main roads are thus affected. It has been noted that the binder is swept from the road, and that the number-two stone ($\frac{1}{2}$-in. to $1\frac{1}{2}$-in. size) is disturbed; in some instances standing on the surface, and in others being left in windrows along the roadside. The Commission is satisfied that a material change in the methods of maintaining stone roads must be made. While old methods have proved satisfactory in the past, they fail under the present usage. The automobile has come to stay and will increase in numbers, and it must be reckoned with."

The 1908 report of the Commission says:

"The destructive work of automobiles during the past year was even more marked than it was in 1906."

These conditions and the opinions of various authorities, have led to a great amount of experimental work, and to the invention of many processes and devices having for their object either temporary treatments which should hold the dust in place, or better, the adoption of more permanent methods which will prevent the formation of dust, and which will be applicable to the many thousands of miles of existing fine roads of broken-stone which Europe has had for nearly a century and

(Courtesy of the Barrett Mfg. Co.)

FIG. 149.—Weston, Mass. On Boston-New York Automobile Route. A turn protected for two years with tarvis.

parts of America for one-tenth as long, and which must now be saved from threatened destruction.

The English engineers have had the advantage of an abundant and cheap supply of coal-tar, and have taken the lead in efforts to find ways to get the best results from applying it —as well as various oil-emulsions—to parts of their great extent of fine and old roads. The French engineers, whose national road system in its general scheme and organization and in the details of its execution and maintenance, is the finest in the world, have devised and widely used methods for applying bituminous binders and coatings to road surfaces, while American engineers have produced the best form of bituminous macadam, or bitulithic, as well as the appliances for making it of uniform reliability and upon a large scale.

General results of experiments.

Americans have also invented a method for the consolidation and asphaltic treatment of sandy and other soils, using a peculiar "rolling tamper" and heavy asphaltic oil, and have made in California many hundreds of miles of dustless roads which are comparatively cheap and which there, in the absence of heavy rains and deep frosts, are durable.

The dust problem is open to two methods of attack: (1) by applying materials to the road which will hold down the dust formed, or (2) by methods of construction designed to reduce the formation of dust, and therefore the wear of the road, to a minimum.

Methods of dust prevention.

The following are the general methods in use for preventing or reducing dust. Each method more or less retains or agglomerates the dust already formed or prevents its formation; the first form being classed as temporary binders and the last two as permanent binders.

1. Sprinkling roads with fresh water.
2. Sprinkling roads with natural salt water.
3. Sprinkling roads with mixture of water and calcium chloride.
4. Sprinkling roads with an oil emulsion.
5. Impregnating roads with special crude oils.
6. Impregnating road surfaces with special coal-tar products.

Fig. 150.—Studebaker Road Oiler.

Fig. 151.—The "Topping" Oiler in Operation.

The most common and the most costly way to prevent dust and to preserve roads is to sprinkle them with water. To keep roads always wet entails expense which is prohibitive even foı city streets and park roadways, on some of which $700 to $900 per mile per year is expended for sprinkling thirty to forty feet width, in order to make them dustless during an average of six hours per day. During dry and hot weather the sprinkling to be effective must be repeated several times per day and the surface alternates between mud and dust. When tried on rural roads it has usually been ineffective, costly, and soon abandoned.

Moisture.

Sea-water is used with results even more unsatisfactory, for although the hygroscopic effect of the deposited salt prolongs the duration of moisture on the road, its presence in the dust and mud adds to their injurious effects; the salty, sticky mud damaging vehicles, corroding metals, and loosening the fragments of stone. Moreover, the accumulated salt, when dry, hurts throats and eyes, damages clothing, furniture and to some extent the feet of horses.

Salt water.

Calcium chloride in solution has been used as a substitue for water, giving a slightly better effect at about the same cost. The principle of this method is that this salt is hygroscopic and when mixed into the road surface (by means of having it in solution in the water of the sprinkling cart) it absorbs additional moisture from the air, thus rendering continuous moisture without the frequent sprinkling necessary with water. It also has a feeble chemical action which unites some of the silicates of the macadam. While the limited experiments in this country have met with some success, its principal use is in England, where the moist climate offers favorable conditions and where over two hundred of the local road authorities are using it increasingly. Its weak solution is non-corrosive and harmless.

Calcium chloride.

The process is best suited to special, limited cases of fine residence streets adjoining large cities, where a municipal supply of hydrant-water is available for sprinkling, and it is specially applicable as preparation for parades or road races. At the best, the effects of calcium chloride are temporary and

make no radical betterment in the road surface. It is not applicable to the great extent of existing broken-stone roads which have no water supply, and which demand permanent treatment to check wear in order to reduce dust, which is more or less true also of all patented solutions.

Oil emulsions are practically mixtures of water, oil and alkali (as ammonia or potash); they are more easily and cheaply applied than oils and they avoid some of the obvious

(Courtesy of Standard Oil Company)

Fig. 152.—Sprinkling Road Oil Emulsion from Ordinary Watering Can.

objections to the use of oils. Their effects on road-dust are usually only temporary, but the results are immediate and travel is not interrupted.

Oil Emulsions.

There are in use many processes, patented and otherwise, for making and applying emulsions of oil, including vegetable oils, crude petroleum, residual oil, creosote-oil, oil-tar, coal-tar, and similar materials, in all of which cases some way is found to emulsify the oily or bituminous material in water, so that the mixture can be spread by a sprinkling or a spraying device, or usually by an ordinary watering-cart. The results are more lasting than those from the chemical salts mentioned above.

Many unsuccessful attempts have been made to use Pennsylvania and Ohio oils having a paraffin base, or some of the Russian oils having a naphtha base, both in their crude form and in emulsions; but these have all failed, because such petroleums are not suited to roadwork, refusing to bind the road materials, having an ill order and forming a greasy slime.

Oils having an asphaltum base, like some of the petroleums of California, Texas, Oklahoma, Kansas, and Kentucky in the United States, and some from Galicia and from Baku in Europe, are the only ones suitable; but if any kind of oil is sprayed or sprinkled in its crude form on a hard macadam road, the result is liable to be most objectionable in regions of normal rainfall, which may mix the oil into injurious mud.

All oil mixtures in which acids or alkalies are used to form soapy emulsions which will mix with water, may be expected to cause the subsequent road-dust, even though it be slight in quantity, to be irritating and injurious to the throat, eyes and skin, in proportion to the acridity of the solvent, and some of the mixtures have been disused for that reason.

Oils.

Attempts have been made since 1894 to use crude petroleum or some of its derivatives, or some oily by-product of gas manufacture, to control and prevent dust. These attempts, many of them unsuccessful, have led to knowledge as to the kinds of oil which are unsuitable and as to the conditions which cause failure. Experience has also shown that oils of certain characteristics, properly applied under the right conditions, give good results at reasonable costs. There will undoubtedly be a great increase in the near future in the use of heated asphaltic oils, not only to prevent dust, but also to improve sandy roads and to preserve gravel and broken-stone roads.

Crude petroleums, which contain the largest proportion of pure asphaltum, give the best results. Petroleum, without asphaltum, having a paraffin base, and those having a naphtha base, are useless, as mentioned above. Some of the California oils as they come from the wells, especially those in the Bakersfield district, producing petroleums having 60 to 84 per cent of pure asphaltum, are valuable mainly for their

use on roads and are used in a crude state with most satisfactory results. Petroleums with asphaltic bases from Texas, Kentucky, Kansas and Oklahoma, some of the Russian oils from Baku, and those from Galicia (Austria) and Borneo are valuable mainly for their volatile parts, leaving residuum which is effective for roadwork after distillation has removed the naphtha, gasoline, illuminating-oil, and other elements which would be detrimental to roads. The by-products thus left are variously known as "residual oil," "roadbed oil," "steamer-oil," and other trade names.

California crude petroleum, heavy in asphaltum, which is 98 per cent pure, was first used for roadwork at Santa Barbara in 1894 and its use in its native state has since been general and in most cases successful; but its general use throughout the country is prevented by difficulties of transportation.

Inexperience in handling road oils.

It has been a common thing during the past few years for some county official, to whom all oils look alike, to buy a car-load of oil of unknown quality and to have it sprinkled from watering-carts in unrestricted quantity, without experienced direction or regard to details of road condition or of weather, and without attempt to remove or to cover the greasy mud caused by sudden rainfall, or to warn the traffic to avoid the fresh oil. It gets on everything—on plants, bushes, trees, vehicles, and clothes, and the results have often been most objectionable to residents and have caused opposition and waste which good management would have avoided.

It has been demonstrated, however, that the objectionable features are avoidable by the successful use of crude and residual oils in various parts of this and other countries. It has also been shown that the oil sprinkled over the surface of a macadam road does not save the road from wear but merely stops the dust; and that a light coating of sand shaken over the freshly-oiled surface will stop spattering of the oil, which was the cause of many of the complaints.

The types of oiled roads peculiar to California have been evolved from the local conditions of material and climate, and the results have been such as to induce efforts to adapt the best

of these constructions to other conditions elsewhere. This consists in mixing heated asphaltic oil with loosened, moistened soil, and consolidating with a "rolling tamper" into a firm, smooth, six-inch layer, which is durable and dustless. In the best practice the crown of a road of soft materials to be oiled must be high and its sides well drained, because water with or without freezing floats much of the oil or gets under the oiled crust and softens it. The hotter the oil when applied, the warmer the weather and dryer the road, the better.

General rules for oiling roads.

In California, according to soil, from 175 to 400 and sometimes 600 barrels (of 42 gallons each) of asphaltic oil are needed per mile of 10- to 16-foot road per year. Two or three treatments are needed on a new road during the first year if the road is of a loamy or sandy nature. After a road has been well oiled and a crust is formed, care must be taken not to break through the crust. Prompt repairs are imperative. It is better to use several successive applications than to flood the road with oil.

Road materials, which if wet would pack firmly under roller or traffic and still remain slightly porous, are the materials which are the best for use by saturating with suitable thick adhesive oils. Such oils suppress dust and harden the road. Road materials of certain clays, earths, gravels, which when wet pack tight or bake in the sun and which pulverize into dust, must be either loosened by harrowing, or otherwise made porous before being oiled, and then must be covered with sand, screenings or the material of the road. Oiling roads is a case where a little knowledge is dangerous, and where much knowledge and experience must be employed to select suitable oils and to use them correctly.

Coal-tar preparations.

Refined coal-tar, produced in gas manufacture and treated to remove its injurious parts and yet to preserve its ductility and to secure uniformity, has been generally accepted by the road authorities of France and England, and also by those road-engineers in the United States who have given the subject most attention, as being the best material with which to improve broken-

FIG. 153.—Automobile Tar-Spraying Machine.

The tar-spraying apparatus is mounted on a steam automobile truck. Steam is furnished by a small locomotive boiler carrying steam at 250-lb. pressure and using bituminous coal or coke as fuel. The engine is mounted beneath the frame and is geared to the hind axle of the machine, which is provided with a differential gear and gears for two speeds. The truck has a road speed of about five miles per hour; during the spraying it travels at about three miles per hour.

The tar-spraying pump is operated by a sprocket chain leading from the rear axle and may be thrown in or out of gear with a clutch. The tarvia is forced into an intermediate cylinder against an air pressure of about 120 lbs. It is then led to the spraying nozzles, which are of the bat-wing type mounted on a horizontal pipe at the back of the machine. The tarvia is carried in an iron tank holding about 1250 gals. and equipped with a steam coil supplied from the boiler to heat the material. In practice, the temperature is held at about 200 deg. Fahr. during the spraying operation.

The weight of the machine complete is 9½ tons; with the tank filled, the weight is over 15 tons. The water tank holds about 200 gals., a quantity which is sufficient to last about three hours.

stone roads; binding the surface of existing roads and bettering the construction of new roads, thereby preventing the formation of road dust. Experience in 1910 favors use of asphaltic residual oils or liquid asphalt.

For success in the use of tar, its quality is most important. If it is heated too much and "refined" too far, it becomes brittle and makes black dust. If not refined enough, the light oils and ammonical liquors will disintegrate it. A reliably uniform product is essential. Good tar, properly applied, is the cheapest and best form of dust-preventer and road-saver, being more effective and durable than any other now known, except asphaltic oil. This decision was reached by the Massachusetts Highway Commission after a year of use and careful observation. It also accords with the opinion of the best-recognized English and French authorities on road construction.

Success of "tarviating."

The success of "tarviating" depends, however, upon the quality of the tar, which must be the best possible; the state of the weather, which must be clear and warm; the condition of the road-surface, which must be clean and dry; the manner of application, which must be rapid and complete.

Too much tar on the surface will be worse than the former mud and dust, being sticky when warm and slimy when wet; and to avoid these serious objections the tar, either hot or cold, is forced in a fine spray into the minute voids and spaces between the stone fragments, by means of pneumatic pressure from a "tar-sprayer," by which the quantity and the distribution are made uniform, and small pools of tar are not left on the surface. Such a tar-sprayer must work so rapidly that full advantage can be taken of warm, dry weather, during which to treat one-half of the width of several miles of road per day.

From this it will be realized what an important part the tar-sprayer plays in the process of "tarviating," and why inventors have been busy devising various machines for increasing the speed and decreasing the cost of application. Eight machines made for this purpose in England and France were subjected to a competitive trial, in 1907, by the English Roads Improvement Association, before road-engineers and representatives of

Tar-spraying machines.

(From Judson's "Dust Prevention.")

Fig. 154.—Spreading Tarvia by Hose from Tank. (Michigan Boulevard, Chicago.)

(From Judson's "Dust Prevention.")

Fig. 155.—Spreading Tarvia from a Slotted Sprinkler.

associations from all parts of Great Britain as well as from France, Germany, Italy, and Egypt.

Some of these machines spread both hot and cold tar under pressure through spraying nozzles, giving rapid and uniform flow and distribution without the need of sweepers; others distributed hot tar by gravity and spread it by automatic trailing brushes. The pneumatic spreading machines are each very effective, having done much good work in England and France, and it is said that their best features may yet be combined in one machine. Few, if any, are yet used in the United States, where distribution is still made by slow gravity flow, usually requiring that the tar be heated and be spread by hand-brooms, at high cost for labor, and at a rate of progress about one-twentieth of that at which better work is done in Europe.

Tests of coal-tar.

The term "coal-tar" is very indefinite, the products of different gas-works varying widely with the kinds of coal used and the methods of treatment, each of which is frequently changed, even at the same gas works. This knowledge has led to careful tests and analyses of different types of coal-tar to determine, if possible, why some succeeded and others failed in road work. Treatments have been made by experts to remove objectionable components and those which would be soluble in rain-water, and to add desirable ones which might increase fluidity or add to the permanence of ductility and adhesiveness, which should be such that after boiling, the coal-tar may be drawn out in long threads. Many failures which had formerly occurred were explained by the former omission of such tests and absence of such qualities, but most road engineers lack the time and equipment to analyze each lot of tar, or to interpret the results of such tests, which are at best costly and uncertain and are of little general utility with the present knowledge of the subject.

There can be no successful system of tarring roads unless there is available a uniform standard and a reliable supply of refined tar. The lack of these in England accounts for many failures, and has so far prevented the universal use which would be expected from knowing of the many successes.

(*Courtesy of The Barrett Mfg. Co.*)

Fig. 156.—Essex St., Somerville, Mass. Built with Tarvia X, 1906. Treated with Tarvia B, 1909.

Every city has its gas-works—often several of them—each using various grades of coal, and frequently changing their methods of treatment to make gas. Even when these features are constant, the quality of crude tar from a given supply-tank will vary as the quantity in the tank varies, the tar drawn from the bottom of a full tank sometimes differing materially from that drawn when the same tank is nearly empty. The resulting crude coal-tars are therefore produced in great variety, so that road-construction which succeeds at one time may fail at another, as most failures have resulted from the use of poor tar.

In "tarviating" experiments in the United States some very crude appliances have been used, but no doubt, as the importance and demand for better roads increases, there will be a relative improvement in the mechanical devices used. The number and the variety of foreign machines for rapidly applying tar are indications of the general recognition of the need for means to quickly treat great lengths of roads during the short periods when weather conditions are favorable, all authorities agreeing that tar should only be applied when both air and road are warm and dry.

Tar-macadam.

Coal-tar and its products are used in the general group of pavements called tar-macadams, composed of hot crushed stone and specially prepared tar or bituminous cement, mixed while hot and compressed in place. Of this group, that which is known as bitulithic pavement seems the most successful for streets, and in lighter form for suburban roads and the interior of villages and small towns.

There is a considerable difference between a tar-macadam, and tarring a macadam road. The latter is a surface treatment while the name "tar-macadam" is applied to any crushed-stone, or crushed-slag construction, in which coal-tar, or a bituminous cement, or a material containing coal-tar or bitumen, or both, is used (instead of water) in binding the filler between the fragments of stone, or slag. The tar or bitumen remains as a fixative to hold in place the stone chips, screenings, or sand forming the filler, binder, or matrix

FIG. 157.—Finished Macadam. Untreated portion in foreground.

for the fragments, thus aiming to better the road (as compared with ordinary, water-built macadam) by excluding water, reducing wear and preventing dust.

Tar-macadam may consist of a tarred layer only, or of tarring all the fragments in the entire road, either before spreading or after spreading in place on the road.

Any good form of the cheaper tar-macadams costs about one-third more than the ordinary water-built macadam of the same kind and depth of stone, because of the added cost of the tar or bituminous cement, the necessary restrictions as to working only in warm and dry weather, and also the need of repairing the injuries done by rain coming on incomplete work. But these initial increased costs are offset, when the construction succeeeds, by longer life of the road and by less expense for cleaning, maintenance, and repairs.

When good, a tar-macadam road is practically dustless and noiseless, offers little tractive resistance, and endures the passage of the rubber tires of high-speed motor-cars; and as it sheds water, it is not heaved nor disintegrated by frost. It has the disadvantage, in common with other pavements, of being slippery when frosty.

Tar-macadam roadways were first built on the London Road at Nottingham, England, at a date variously stated from 1840 to 1845, and at Sheffield soon after. Other similar roads have since been built at many times and places in England and in France, and some in the United States since 1900. The earlier ones used crude coal-tar, mixed by hand with various kinds of stone, and often produced failures because of the poor quality of the crude tar, or because of rain or cold during construction. Many of the old ones, however, are still in satisfactory use, as well as many new ones.

Mixing tar-macadam.

In recent years the necessity of having properly refined tar has become generally known, and improved appliances for heating and hand-mixing the tar and stones have been used with much better results than formerly as to cost and character; the mixing has been effectively done in some cases with an ordinary concrete mixer.

FIG. 158.—Petrolithic Outfit at Work, Ventura, California.

FIG. 159.—Petrolithic Pavement through the Orange Groves, California. Grade 10°.

Steam-operated machines have been produced which mechanically heat and mix stones and tar, preparatory to spreading it, cold, upon the roads. The tar-spraying machines and tar-spreading machines adapted to tarring the stone in place, after it has been spread on the road, have not as yet been much used for making tar-macadam, but for which they are well suited, although the methods of construction have been very radically improved since 1905.

The "Gladwell" system.

The "Gladwell" system is a method of surfacing macadam roads, either old or new ones, with a tar-macadam top which gives some of the effects of tar-macadam, and at a less cost. It consists in imbedding a two-stone course of untarred, clean, crushed stone in and between two layers of tarviated, dustless stone chips, forming a matrix which is worked, by judicious rolling, into the spaces between the stone fragments from below upward and from above downward, finally sealing the surface so as to be waterproof by hot tarvia and granite chippings.

The system was devised by Arthur Gladwell, who has charge of road construction and maintenance at Eton, near Windsor, England, and was first used by him in July, 1906. It has since been successfully used on the roads along the Thames, and elsewhere in England. Its low cost and ease of construction, and especially the fact that most of the work may be done in ordinary weather, will no doubt lead to its extensive use in the United States.

Use of tar-macadam in America.

There is as yet no general use of tar-macadam on rural roads of the United States and Canada, such work having been done only on a small scale in an experimental way by the road departments of some of the States, and by a few towns and villages. The use of the high-class bitulithic and similar pavements has been confined to urban and suburban streets. The United States Office of Public Roads has done some useful work at Jackson, Tennessee, and the results as published have been generally read and used as the basis for other experiments. The report says:

"A tarred street is dustless in the same sense that an asphalt

Fig. 160.—Spike Disc Harrow, used for pulverizing clods and mixing oil in Petrolithic pavement construction.

Fig. 161.—Roller Tamper.

street is dustless, though a fine sandy powder wears off as in the case of asphalt. In driving over a tarred macadam road, the lessening of vibration and noise is at once noticeable. The ordinary macadam produces a constant succession of slight jars upon a steel-tired wheel and there is a relief felt at once in driving upon a road treated with tar."

The Office of Public Roads continued to give special attention to the subject during 1908 and 1909, and expressed the opinion that surface treatments were palliatives rather than dust-preventives, and that a more lasting method would be "the use of well-tarred sand as part of the binding material and to fill voids," applying a layer of such tarred sand to the rolled base-course, over which the top course should be spread and rolled until the tarred sand should work down into the base-course and up into the top-course. The surface being then finished by an application of tar covered with fine chips or sand and rolled until smooth and uniform. This suggested method is practically the same as the "Gladwell" system.

Rock asphalt macadam.

Rock asphalt macadam construction gives good results, but the cost of transportation has limited its use to the vicinities of the natural formations of the peculiar sandstones and limestones which are impregnated with bitumen and are known as "rock-asphalts."

The natural formations which occur in Arkansas, Oklahoma, and Kentucky, are sand-rock impregnated with a proportion of bitumen varying from a trace to a maximum of thirteen per cent, six per cent being about the least useful proportion.

The European supplies are those of France, Sicily, and Switzerland, and are bituminous limestones formed by natural combinations of about twelve per cent of bitumen with about eighty-eight per cent of amorphous carbonate of lime, and were first used for roads in Paris in 1854, and since then have made the comparatively small extents of asphalt pavements in European cities, being too costly for general use and much more slippery than the similar city pavements made from the American sand-rock asphalts.

For less costly roadways in the cities of the southwestern portion of the United States, sand-rock asphalts from the formations in Arkansas and Kentucky have been combined with ordinary macadam, making a pavement that is not slippery because the fragments of stone imbedded in the ground sand-rock asphalt give a good foothold, but which needs considerable care and which must be kept clean.

The bitulithic pavement is the best known combination

(From Judson's "City Roads and Pavements.")

Fig. 162.—Laying Bitulithic Pavement, Toronto, Ont.

Bitulithic pavement

of crushed stone and bituminous binder, and is composed of fragments of stone which are held firmly and free form attrition, and hence form no dust. It differs from other bituminous macadams in that the proportions of the several sizes of fragments of crushed stone, from two inches in size down to dust (which form about nine-tenths of the final mass), are accurately determined and are so combined in such proportions of the six or more sizes that the final voids between the fragments after rolling do not exceed 10 per cent, or less than half the ordinary voids

in rolled stone. This puts the fragments into actual and firm contact, so that the addition of 10 to 12 per cent by weight (12 to 16 per cent by bulk) of bituminous compound fills the remaining voids and makes a solid and impervious mass. This result requires experienced care and skill in selecting and combining the best materials, including testing and analyzing the components of the bituminous cement. The pavement thus produced is one which water cannot penetrate, and it supports the passage of heavy and high-speed vehicles without any loosening of the bituminous filler and without abrasion of the fragments of stone, so that no dust comes from the pavement or its materials.

With the present general knowledge of this form of pavement which has been acquired since 1901, opinions are now of less moment than in its first years of use, but the general opinion of the leading authorities is substantially that expressed by the Massachusetts Highway Commission:

"The bitulithic pavement is undoubtedly the best form of pavement to give the desired results (durability and freedom from dust under fast motor-car travel), but it is too expensive for many locations."

It was first used in 1901 in Pawtucket, R. I., where it was laid on a 12 per cent grade, and during the same year sample areas were built in seven cities, aggregating about one mile of 30-foot width. The success was immediate, and the use increased each succeeding year, so that at the close of 1907, 6,500,000 square yards, equal to 422 miles of 30-foot roadways, had been laid in one hundred and sixty-six cities of the United States and Canada, including cities in the region of extreme cold, as at Edmonton, Province of Alberta, Canada, and Glacé Bay, Nova Scotia, and in the South at El Paso, Texas, and at Atlanta, Georgia. This widespread success has induced imitations and consequent litigations, which are further evidences, if such were needed, of the merits of the construction.

The elaborate outfit of laboratory and machinery and skilled direction required to successfully produce this pavement would at first seem to limit construction to the vicinity

(*From Judson's "Dust Prevention"*)

FIG. 163.—One-car Portable Bitulithic Railroad Plant. (Set up ready for operation.)

(*From Judson's "Dust Prevention."*)

FIG. 164.—Semi-Portable Bitulithic Paving Plant.—End view.

of permanent plants, and this idea is strengthened by visiting such a plant and examining the work in progress. There have, however, been built and patented a number of "semi-portable bitulithic paving-plants," each permanently set upon a platform-car. These outfits make it possible to build this pavement in many widely distant places and to give to all of them equally reliable results. The accompanying illustrations, showing this semi-portable bitulithic paving-plant, are lettered to accord with the following key:

A. Boiler and engine.
B. Rotary driers for heating and drying stone.
C. Elevators for delivering the stone to the driers.
D. Elevators for conveying the heated stone to the separating-screens.
E. Sectional screen for separating the stone into several sizes.
F. Sectional bins for storing the several sizes of stone after separation, and delivering same to the weighing-box.
G. Weighing-box resting on a multiple seven-beam scale for accurately weighing each size of stone in predetermined proportions and delivering same into the mixer.
H. Twin pug mechanical mixer, having two shafts revolving in opposite directions with arms or blades interlocking each other.
I. Mixing platforms under which wagons back for taking the bitulithic mixture as delivered from the mixer.
J. Ogee-bottomed bitumen-melting tanks.
K. Bitumen weigh-bucket conveyor and dial-scale, so arranged as to indicate both gross weight and tare.
L. Rotary exhaust fan for providing induced draft to the rotary driers.
M. Dust-separator for reclaiming dust drawn by the exhaust fan from the stone while it is drying.
N. Steel frame for supporting the mixing-platform, mixer, scale, sectional hot-stone bin, and sectional screens.
O. Steel car on which the semi-portable or railroad plant is permanently set.

CHAPTER XII

STATE AID LAWS*

Most of the state-aid laws are accumulations of laws and amendments passed session after session without definite logical arrangement, and without any carefully thought out general plan in mind. New York, however, appointed a special commission which studied the question very carefully for a year, both in their own state and in neighboring states. This commission proposed a bill which was passed, and went into effect in January, 1909. This bill replaces all previous highways law, and rearranges the whole highway work of the state, counties and towns so as to bring the separate units into logical relations to each other.

As a result of the study of the different state laws, a model bill providing for state aid was drawn up by the United States Office of Public Roads at Washington, D. C., to embody the best results of the experience of all of the states based on the workings of each of the state aid laws under their local conditions.

Briefly stated, the three things that are most fundamental for the successful working of state aid are: (1) an equitable plan for distributing funds; (2) putting the spending of the money in the hands of expert men; (3) providing for such a form of commission that the work will be carried on without regard to political considerations.

On looking over the summaries of the state aid laws, it will be found that the various states pursue a variety of methods in distributing the aid to the localities where it is used. Some states leave this matter entirely in the hands of the com-

* Abstracted from First Biennial Report of the Highway Division, Wisconsin Geological and Natural History Survey, 1909.

mission, or limit the commission only by stating that not over a certain maximum or not less than a certain minimum amount shall be spent in any county. One state divides the amount equally between the counties; another divides the money between the counties on the basis of the total number of miles of road in each county; other states divide the money in proportion to the county; other states divide the money in proportion to the amounts asked for, so that if the aggregate of the amounts of state aid petitioned for is twice that which the legislature has appropriated for the purpose each town or county petitioning receives one-half of what it asked for.

Distribution of state aid funds.

On account of the almost necessarily inequitable manner in which taxes are generally assessed upon property, it will be very evident that the distribution of the fund must become more or less inequitable in certain particular cases.

In the first place, the method of leaving the distribution of the money entirely in the hands of a commission is distinctly inadvisable, as it puts altogether too much responsibility on a very small group of men, whose knowledge of conditions, even though they may be ever so well intentioned, would hardly be broad enough to qualify them to do justice to all the counties and to the several hundred towns in any large state.

To divide the money equally among the counties would be very markedly wrong, as counties with a comparatively scattered settlement would receive as much as large, well-settled counties.

To divide tne money on the basis of the total number of miles of road in each county would also be inequitable, as some of the less wealthy and less populous counties might have as many or even more miles of road per square mile of area than some of the wealthier and more settled counties.

To divide the money pro rata with the amounts asked for would do injustice in that counties which are able to ask for large sums might prevent poorer counties able to ask for only very small sums from getting their proper share. For instance, one county, which is neither large nor wealthy, might petition

$1000 of state aid. Another county, comparatively populous and wealthy, might ask for $40,000 or $50,000 a year. If the total amount of state aid asked for were twice the state aid appropriation, the former county would only get $500 where it should have had $1000, while the latter would get $20,000 where in justice it might only have been given $15,000.

The idea of the most just apportionment of the state aid fund that first occurs to anyone studying the question is a distribution on the basis of valuation. Such a distribution, however, presents difficulties in that the amount of state aid given to some of the poorer counties would not be sufficient to amount to anything unless an exceedingly great state aid fund were appropriated.

Supervision of construction.

The second important point to which attention should be directed is the final authority in the supervision of the actual construction. It will be noticed by the summary of the state laws that follows, that every state giving state aid gives authority to its state highway officers to say what methods of work shall be pursued and how the roads shall be constructed. This matter is important because it has to do with the primary purpose of state aid; that is, to secure efficient, well-planned work on our highways, and the careful expenditure of the state aid money, instead of the haphazard work, entirely lacking in plan, which is secured under the present system.

In order to get efficient spending of our road money we must profit by the experience of other countries. In France the best engineers that their colleges produce are taken into the Department of Roads and Bridges, and the state's money is spent under their direction. If we are to build the best roads with least cost we must have efficient engineering departments in charge of the work with authority to say that the best methods only shall be used. In order that such an engineering force might not be so large as to be unwieldy, and to promote economy, it should be provided that it should work, in so far as possible, through competent county highway commissioners. But in order to secure efficiency and uniformity

in the work the final authority should rest in the state engineering department.

Form of commission.

One of the most important questions to be considered in framing a state aid law that will work successfully is the form of the state commission or body that has general control of the work. The importance of this point lies entirely in whether or not the state highway work is to be controlled by political considerations with the resulting inefficiency of the actual road building, or whether it is to be controlled entirely in the interest of efficient road work without regard to political considerations. Of course no one would say anything else than that this work must be kept out of politics. But there is great danger that political influences may creep in as they nearly always do, under the guise of cheapness or efficiency of administration. For this reason the following statements deserve particular attention from everyone interested in the success of the state aid movement.

A study of the laws of the various states reveals the fact that there are four distinct plans for the control of the state highway department.

1. One state highway commissioner or engineer appointed by the governor for a definite term of years. Five states have this plan.

2. A commission of three men paid for their full time and appointed by the governor for a definite term of office. Two or three states have this type of board.

3. A commission appointed by the governor for a definite term of office, but serving without pay and giving only general direction to the work, which is under the active direction of a state engineer selected and hired by them for a period coincident with satisfactory service. This and the fourth method are analogous to a business corporation with its board of unsalaried directors and the general manager carrying out the details of the general policies laid down by them. Six states have boards of this kind. These states get able men of wide experience and good business ability to serve on their commissions.

4. An ex-officio board such as is recommended in a model state aid bill by the United States Office of Public Roads for the particular purpose of avoiding politics in the state aid work. That bill makes the professors of civil engineering in three different colleges members of the state highway board by virtue of their position. Such a commission maintains its existence without regard to what particular man holds one of these professorships. It need not be made in this way, however, but could be composed of the holders of any non-political positions either in state employ or otherwise, and the same freedom from politics enjoyed. Seven states have this form of commission. In no one of them, so far as information is available, has politics become a factor in the state road work, but the same cannot be said of states having other forms of commissions.

DIGEST OF STATE AID LAWS

In the following digest of the laws of various states, the states considered are not all of those providing for state aid for road building, but are sufficient in number to give a fair idea of the various methods used in all states. The states whose laws are summarized are:

New York	New Jersey
Maryland	Washington
Virginia	Ohio
Massachusetts	Michigan
Connecticut	Maine
Pennsylvania	Rhode Island

In order to make it as easy as possible to compare the provisions of the laws they are grouped under various headings. These headings are:

State Highway Department.
State Aid Highways.
State Aid Fund.
Powers and Duties of Counties.
County or District Highway Engineers.
How Localities get State Aid.
Construction of State Aid Highways.
Payment for State Aid Highways.
Maintenance of State Aid Highways.

State Highway Department

In the model bill of the United States Office of Public Roads the state highway commission is made up of the professors of civil engineering in three different colleges. A commission of this kind was selected for the express purpose of avoiding political influences in the work. These commissioners receive no salary, but are paid their actual expenses in attending meetings, etc. They exercise general supervision over the state highway work, appoint the state engineer to hold office during satisfactory service, and fix his salary. This engineer has charge of all the state road work and appoints his engineering assistants and clerical force, subject to the approval of the commission. The state engineer may be consulted by county, city or town officers concerning roads and bridges. **Model bill.**

New York has a state highway department in charge of three commissioners appointed by the governor for a term of six years, one of them going out of office every two years. One of these commissioners must be a practical civil engineer with experience in the construction of highways and bridges. The chairman of the commission, who is designated by the governor, is paid $6000 a year and the other two commissioners $5000 a year each. This commission has general supervision over all state aid work. They appoint a chief road engineer, a chief bridge engineer, and such clerks and assistants as are needed. This commission apportions the state highway money among the various counties of the state in a manner they think equitable. They have authority to regulate the digging up for any purpose of any road built with state aid, and are instructed to aid in promoting highway improvements and to carry on experiments in road construction. **New York.**

This state has put the general supervision of its highway work in the hands of an ex-officio commission, the Geological Survey Board. The commission is composed of the holders of the following positions: Governor of the state; Comptroller of the state; President of Johns Hopkins University; President of the State Agricultural College. This board receives no salary, but is reimbursed its actual expenses for attending meetings, etc. They appoint the chief engineer and fix his salary. They allot the state aid money to the various counties of the state as petitioned for, the allotment to each county being made on the basis of total **Maryland.**

road mileage. The chief engineer makes the surveys, plans, and specifications for roads built under state aid.

Virginia. The state highway commission is an ex-officio board composed of the professors of civil engineering at the University of Virginia, Virginia Agricultural and Mechanical College, and the Virginia Military Institute. Under their direction is the state highway commissioner, who is appointed by the governor for a six-year term. This commissioner must be a civil engineer well versed in road building, and a citizen of the state. His salary is $3000 per year. The commission serves without pay, but is reimbursed actual expenses for attending meetings. The state commissioner has authority to hire engineers and assistants. The commission apportions the state aid money in proportion to the amount of state taxes paid by each county. This state also aids the counties in road construction by loaning them its convicts to work upon the roads.

Massachusetts. This state has a highway commission of three men appointed by the governor for a term of three years, one term ending each year. The president of the commission receives $3500 and the other two members $2500 each per annum. This commission appoints a secretary who is practically state engineer, and fixes his salary. They exercise general supervision over the state aid work, and employ such engineers, clerks, etc., as are necessary. The apportionment of the state highway fund is left entirely in the hands of this commission, with the single restriction that they cannot build more than ten miles of road in any county in a year. The commission has absolute authority over the digging up of state aid roads for any purpose. They can purchase such machinery as is needed in the building of state aid roads.

Connecticut. This state has a single highway commissioner appointed by the governor for a four-year term at a salary of $3000. In addition to his salary he is provided by the state with a touring car and a man to run it to assist him in getting about the state in connection with his duties. The commissioner appoints such deputies and engineers as are needed and fixes their salary with the provision that the total limit of salaries is $25,000 a year. The commissioner allots the state highway fund among the various towns. He has authority to purchase stone crushers and loan them to the towns in the state desiring them.

This state has a highway department under the direction of a single commissioner paid a salary of $6500 per annum and

appointed by the governor for a term of four years. The law specifies that this commissioner "shall be a competent civil engineer and experienced in the construction and maintenance of improved roads." This commissioner appoints a deputy at a salary of $3600, and an assistant deputy at $3000, twelve engineers and a chief draftsman at $2400 each and such other assistants and clerks as are needed. Among his duties are the promotion of highway improvement, the regulation of the digging up of the state aid roads for any purpose, and the collection of information regarding road building.

Pennsylvania.

This state has one highway commissioner appointed by the governor for a term of three years, at a salary of $5,000 per annum. No qualifications are specified in the law. The regulation of the digging up of state aid highways is left to the counties. The state commissioner has supervision over the surveys and plans for state aid roads, and the location of roads to be improved must meet his approval. He has authority to reject all unsatisfactory road contracts which the county boards may desire to enter into. He appoints the supervisors on all work done on state aid roads, both in construction and maintenance.

New Jersey.

This state has a highway board composed of the state auditor, the state treasurer ex-officio, and the highway commissioner, who is appointed by the governor for a four-year term at a salary of $2500 per annum. This commissioner must be an experienced civil engineer. He has authority to appoint needed engineers and assistants. The state highway board apportions the state money among the counties and lets all contracts for the building of state aid roads.

Washington.

There is a single state highway commissioner appointed by the governor for a term of four years at a salary of $2500. The law requires him to be a competent civil engineer with experience in highway construction. It is his duty to instruct and assist town and county officers in the making of improved roads, and to collect information and make tests and experiments in road building. The location of all roads to be improved must meet his approval and all contracts for their improvement are let by him in the name of the state. He appoints his assistants and inspectors for the state aid work.

Ohio.

There is one highway commissioner appointed by the governor for a term of four years at a salary of $2500. The only

qualification specified in the law is that he shall be a citizen of the state. He has authority to appoint needed clerks and a deputy commissioner, and is instructed to hold public road institutes in each county, at which the attendance of town and county highway officers is required. These local officers draw their regular pay and expenses for attending these meetings. The state commissioner furnishes plans and specifications for roads and bridges, and allots the state aid fund to the towns or counties petitioning. He has authority to refuse to allot any money to a town or county which does not maintain its state aid roads properly. When state aid roads are completed it rests with him to decide whether or not they have been well enough constructed to merit the payment of the state money.

Michigan.

There is one highway commissioner appointed by the governor for a term of four years at a salary of $2500; he must be a civil engineer. He appoints an assistant, who must be a civil engineer also, and must have the further qualification of being experienced in road building. He also appoints his clerks and stenographer. It is his duty to advise the towns on road and bridge construction, to apportion the state aid money in accordance with the law, make all surveys for the improvement of state aid roads and determine the location of the roads to be improved. He appoints inspectors for the work under progress. Meetings are held in each county once a year by the highway commissioner.

Maine.

This state has a board of five members appointed by the governor for a five-year term of office, one member being appointed each year. This board receives no salary, but the members are reimbursed their expenses for traveling done in connection with their duties. They have complete authority over the state roads, and employ such engineers and let such contracts as they see fit.

Rhode Island.

STATE AID HIGHWAYS

This provides the state aid highways are to be selected by the country boards, subject to the approval of the state highway department.

Model bill.

This state has three systems of roads: (1) roads built entirely at state expense, which are selected by the legislature; (2) county roads, which are selected by the county boards, subject to the approval of the commission, 50 per cent of the cost of which is paid by the state, 35 per cent by the county and 15 per cent by the town; (3) local

New York.

roads, which are aided by the state, but receive no county aid. The state pays from one-third to one-half of the cost of the local roads. The local roads to be improved are selected by the town board and the town highway superintendent, subject to the approval of the commission.

No road in the state of New York is improved with the assistance of the state until both the location and the manner of improvement have been passed upon favorably by the commission.

Maryland. The highways to receive state aid are selected by the county commissioners subject to the approval of the state highway department. If the county commissioners refuse to act in regard to any road the owners of two-thirds of the adjoining lands can compel them to petition the state highway department by agreeing to pay 10 per cent of the cost.

Virginia. The state aid roads are selected by the county board, but both the location and the method of work must approved by the state commissioner before any state money is granted.

Massachusetts. The Massachusetts law provides that counties, cities and towns may petition the state highway commission for aid. The location and manner of construction of roads must be approved by the state highway commission before aid is granted.

Connecticut. The highways to receive state aid are selected by the state commissioner. The local people of a township may petition for state aid, but this petition is general and the particular road to be improved is selected by the commissioner, who is directed by law to improve only the main highways leading from one town to another.

Pennsylvania. In this state the township supervisors or county commissioners desiring state aid petition the state highway commissioner, who may grant the petition if he approves of the location. The kind of road to be built rests entirely with the state commissioner.

New Jersey. Roads to be improved with state aid are selected by the county boards, who may also adopt as a state highway any road which has been previously improved without state aid. The location and kind of road to be built must have the approval of the state highway commissioner before state aid is granted.

This state has four kinds of roads: (1) state roads constructed entirely by the state, which are selected by the legislature;

Washington. (2) state aid roads; (3) improved roads which are paid for entirely by the county; (4) town roads which are built by the local people. The location and method of improvement of state aid roads must have the approval of the state highway board before state aid is granted.

Ohio. The roads to be constructed by state aid are selected by the county board. If the county board does not act the owners of 51 per cent of the linear frontage may petition. The location and kind of road to be constructed are subject to the approval of the state commissioner. If more petitions are made in one year than there are funds available the state commissioner and the county board together decide which shall be constructed first.

Michigan. In this state the county board of highway commissioners selects the roads to be built with state aid. After the road is completed the state highway commissioner must approve the method of construction before state aid is granted.

Maine. The roads to be built with state aid are selected by the towns subject to the approval of the state commissioner.

Rhode Island. This state has no roads which are built with state aid. The only classes of roads which it has are those paid for entirely by the state, which are selected and constructed by the state board, and the local highways, constructed and maintained by the localities without any state assistance.

STATE AID FUND

Model bill. This bill provides that the money shall be raised by a general tax and apportioned according to the assessed valuation of the counties.

New York. The state aid fund in this state consists of a bond issue of $50,000,000. It is apportioned by the state commission among the counties "equitably and without discrimination," taking road mileage and improved roads into consideration.

Maryland. The state aid fund is made up of a general appropriation of $200,000 annually and a five-million-dollar bond issue. The annual appropriation is apportioned by the state board according to the total road mileage. The five-million-dollar bond issue is used to pay the whole cost of certain state roads which are selected by the state board.

The state aid granted by Virginia is in two forms. They loan state convicts to the counties and have an appropriation of $25,000 for the transportation and caring for these men. They also have an annual money aid appropriation of $250,000, with a separate appropriation of $16,000 for the support of the state highway commission. In addition 10 per cent of the state aid fund may be used for the necessary engineering on the roads under construction.

Virginia.

The state aid is apportioned by the commission on the basis of the amount of state taxes paid by each county. If any county does not apply for its share it is divided among other counties asking for more than is first apportioned.

The state fund of this state is made up of an annual appropriation of $450,000, with a separate appropriation of about $40,000 for the support of the commission, approximately $60,000 received from automobile license fees which is used in maintaining roads. The state aid is apportioned by the commission as they think equitable and under the restriction that not over 10 miles of road can be built in a single township in one year.

Massachusetts.

The state aid fund is made up of an annual appropriation of $750,000. This is apportioned by the state commissioner under the limitation that not more than $10,000 can be spent in any town in one year.

Connecticut.

The state aid fund is made up of an appropriation of $2,000,000 for 1908. This is apportioned by the state commissioner among the counties in proportion to to total road mileage. Apportionments not called for by any county are reapportioned among the counties desiring more than their first apportionment.

Pennsylvania.

The state aid fund is an annual appropriation of $400,000. This is apportioned among the counties by the state highway commissioner.

New Jersey.

The state aid fund is made up of an annual tax of one-half mill on all the property in the state. This is used for the building of "state aid" roads. "State roads," which are paid for by the state alone, are covered by separate appropriation of $225,000 for the year 1908. The state aid fund is apportioned to the counties in the order in which petitions for the improvement are received.

Washington.

The state aid fund is an appropriation of $158,000 annually. It is divided equally among the counties. Counties which have previously built roads at their own expense are entitled to reimbursement from the state aid fund.

Ohio.

Michigan. For the year ending June 30, 1909, the Michigan appropriation was $150,000. The salaries and expenses of the office of the state highway commissioner were paid from the state general fund in addition to this. State aid money is apportioned among the towns and counties on the basis of work done in the order in which the applications are received.

Maine. The state aid fund is an annual tax of one-third of a mill on all the property in the state. It is apportioned to the counties by the state highway commissioner on the basis of total road mileage. The county apportionment is then divided among the various towns in the county on the pasis of valuation.

Rhode Island. The state aid fund is a bond issue of $600,000 for the two years 1907 and 1908. It is apportioned as the state board sees fit within the limits that not over one-third nor less than one-seventh of the total amount can be spent in one county during the year.

POWERS AND DUTIES OF COUNTIES

Model bill. The authority of the county board ends with selecting the road and paying their share of the cost of construction and maintenance; both construction and maintenance being looked after by the state.

New York. In this state the county board may levy a tax for permanent improvements. They may borrow money in anticipation of taxes. They must provide lands for the right of way for new state or county roads. They may elect a county highway superintendent for a four-year term, but if they do not choose to elect such a man the state commission appoints a district superintendent over a number of counties and the county is then obliged to pay its share of his salary. The removal of the county superintendent of highways is in the hands of the state commission. The town is liable for all damages due to defects in any road.

Maryland. In this state the county commissioners petition for the road improvement. They let the contract for the construction of roads subject to the approval of the state board, must provide lands for the right of way and relocation, may elect a county highway engineer, and must keep the state aid roads in a condition of repair satisfactory to the state board.

The county board petitions for the road improvement, and after this has no further authority or responsibility excepting

to pay their share for the construction and maintenance, both of these being in the hands of the state commissioner. The county engineer, if there is one in the county, is selected by the state highway commissioner, but paid by the county board. **Virginia.**

After petitioning for state aid the county has no further authority or responsibility excepting to pay for its share of the cost. **Massachusetts.**

In this state the county is not an important unit of government, and the state deals only with the towns. After the town has petitioned for state aid matters are entirely in the hands of the state commissioner. **Connecticut.**

The county may petition for the improvement of a road, and may enter into a contract with the state to do the actual work of construction. The county elects a county highway engineer, and is responsible for all damages due to defects on state aid roads. **Pennsylvania.**

The counties may raise a tax for the construction and repair of state aid roads amounting to five mills. They may bond for as much as 3 per cent of the assessed valuation for road purposes. Counties have the authority to acquire property and machinery for road purposes. They must elect a county supervisor of roads as soon as the first state aid road is completed in that county. This supervisor may be removed by the county or by the state commissioner. The county has control of the state aid roads within its boundaries and must keep the same in a state of repair satisfactory to the state commissioner. The county must accept as a state highway any road built by the local people in a manner approved by the state highway commissioner. The county has authority to regulate the digging up of state aid roads for any purpose. **New Jersey.**

The counties may levy a four-mill tax for road improvement and can bond to the amount of 5 per cent of the valuation. They may acquire property and machinery for road purposes. The county surveyor must be a civil engineer, and his title is changed by the highway law to county engineer. The counties must maintain the state aid roads under the orders of the state commissioner. **Washington.**

The county board may levy a tax of not to exceed one mill for road improvements and may issue bonds to pay for state aid roads. They may elect a county highway engineer. They may secure lands for right of way **Ohio.**

and must maintain the state aid roads in a manner satisfactory to the state commissioner.

Michigan. The county elects by popular vote a county board of highway commissioners of not over five men. This board of highway commissioners may levy a tax of not to exceed two mills for permanent improvements. The counties may bond up to 5 per cent of their valuation, and must maintain the state aid roads to the satisfaction of the state commissioner or be cut off from further state aid. The county is responsible for damages due to defects in state aid roads. This board selects the system of county roads to be improved with state aid.

Maine. The county boards designate the roads to be permanently improved on the petition of the towns, subject to the approval of the state commissioner. They may levy a tax of one-third mill for improvements on state aid roads. This amount must be spent under the direction of the state commissioner. Towns may raise an additional amount if they want state aid.

Rhode Island. This state does not deal with the counties at all in its permanent improvements.

COUNTY OR DISTRICT HIGHWAY ENGINEERS

Model bill. County engineers are appointed by the state engineer on the approval of the commission.

New York. The county board elects a county highway engineer for a term of four years and fixes his salary. If the county board does not choose to elect, the state commission appoints a district engineer to have charge of the work in several counties. Each of these counties is then obliged to pay its share of his salary. The qualifications of the county highway engineer are set by the state civil service commission, and only those who have passed a satisfactory examination are eligible. His duties are to advise with towns and village officers, have charge of the construction of new roads in his county, and the maintenance of all state aid roads, and such other duties as the commissioner or the county board assign to him.

Maryland. The county engineer, when there is one, is appointed by the county commissioners. His term is indefinite, and continues with satisfactory service. The law specifies that he must be a civil engineer. He has charge of all the county road work, and the local road superintendents are under his direction.

Virginia. The county engineer is appointed by the state highway commissioner and the law provides that he shall be paid at not to exceed the rate of $1200 a year for the time actually employed. He must be a civil engineer.

Massachusetts. This state has no county engineers, but the state commission appoints division engineers to have charge of the work in each of the five divisions of the state. These engineers are paid by the state and must be experienced civil engineers.

Connecticut. This state has no county or division engineers. The state highway commissioner and his assistants do all the engineering work, usually hiring engineers for each particular job.

Pennsylvania. The counties in this state have county engineers who make plans and surveys subject to the approval of the state commissioner.

New Jersey. The county board must elect a county supervisor of roads on the completion of the first state aid highway in that county. His term is three years, and his compensation is fixed by the county board. In some counties the engineer is paid as much as $6000 a year. He may be removed by the county board or by the state commissioner. He has charge of the improvements made in his county and the maintenance of the roads. The only qualification named is that he shall be a "suitable person."

Washington. The county engineer is elected by popular vote for a two year term. His salary is $5 per day for time actually spent on the work in the smaller counties, and the same as the county auditor in large counties. The law provides that he must be a civil engineer. Among his duties are the keeping up of a county road map and the preparation of profiles of roads, reporting on proposed improvements and supervising the road work done in his county.

Ohio. It is optional with the county boards to elect county engineers. The state highway commissioner's office, however, does practically all the engineering on state aid roads.

Michigan. They have no county highway engineers in this state, but instead have a county board of highway commissioners elected by the people. This board may be from one to five men as the county board chooses, and the term depends on the number. One man goes out of office every two years. If there are five men the term is ten years, if there are three men the term is six years and so on. The only

qualification named is citizenship in the county. This board has all authority over county roads. Their salaries are fixed by the county board.

Maine. They have no county or district engineers in this state.

Rhode Island. There are no county or district engineers in this state.

HOW LOCALITIES GET STATE AID

Model bill. The county board petitions the state highway department.

New York. The county board petitions the state highway commission.

Maryland. The county board petitions the state highway department, but if the board refuses to act the owners of two-thirds of the adjoining lands may force the county to petition by agreeing to pay 10 per cent of the cost.

Virginia. The county board petitions the state highway commissioner.

Massachusetts. Counties, cities or towns may petition the state highway commissioner, for aid, but the commission has practically nothing to do with cities.

Connecticut. The towns vote money for road improvement and petition the state highway commissioner, who selects the road to be improved. If a town fails to vote money to improve an important road which needs it badly the state commissioner is empowered to go ahead on his own initiative to improve the road, and the town's share of the expense is taken out of any subsequent allotments that may be made by the state.

Pennsylvania. The town petitions the county, and the county then petitions the state commissioner. Towns may petition the state commissioner directly if they are willing to pay the county's share of the cost as well as their own. The owners of a majority of the assessed valuation of the real estate in the town can by petition compel the town board to request the county board to apply for state aid. The petitioners as such are not obliged to assume any part of the cost of building the road.

New Jersey. The governing board of any town, county, borough or village may petition the state highway commissioner. If the property owners on a particular highway desire to have it improved and the officials refuse to act they can improve the road at their own expense and the

county board is obliged to accept it as a state highway and thereafter maintain it.

Washington. The county petitions the state highway board. The owners of two-thirds of the property on any road may compel the county to petition for improvements on that road.

Ohio. The county board petitions the state highway commissioner for aid, and if they do not act voluntarily the owners of 51 per cent of the frontage may compel them to act.

Michigan. The town or the county may petition the state highway commissioner. If they issue bonds and build several miles of road in one year they receive their share of state aid on two miles of this road each year until they receive the total amount of state aid which they are entitled to.

Maine. In order to get state aid the towns must raise an extra highway tax of from 1-12 to 1-4 mill, according to the valuation of the town, and petition the state highway commissioner. If he approves the petition the road is built.

Rhode Island. Rhode Island does not deal with the localities at all but builds the roads directly under the state commission.

CONSTRUCTION OF STATE ROADS

Model bill. The construction is in the hands of the state engineer, who makes plans, surveys, estimates, etc. The machinery necessary is provided by the state and its operation paid for by the county. All work costing over $2000 is let by contract. The state engineer lets all contracts in the name of the state. Partial payments on work in progress must not exceed 85 per cent of the cost according to the engineer's estimate. The inspection of the work during construction is entirely in the hands of the state engineer.

Grades and width of improved surface are fixed by the state engineer.

New York. The construction of state aid roads is entirely subject to the state commission. Plans, estimates and surveys are made under their direction and they let all contracts for work. The county must furnish the right of way for relocations. Towns or counties may bid on the construction the same as any contractor, and if they are low bidders the commission lets the contract to them. The inspection of the

work during construction is done by the state, and if the work is not being properly carried on the state has authority to stop it and relet the contract.

Grades and width of improved surface are fixed by the state commission.

Maryland. The construction of state aid roads is all under the supervision of the chief engineer of the highway division. Plans, estimates and surveys are made by him. Contracts for work are let by the county board subject to the approval of the engineer. The inspection during the progress of the work is done by the state.

Grades and width of improved surface are fixed by the state.

Virginia. Plans, surveys and estimates of state aid work are made by the state highway commissioner. All work is done under contract let by the state commissioner. The counties may bid on work in competition with other contractors. The inspection of the work in progress is done by the state commissioner or some of his assistants.

Grades and width of improved surface are fixed by the state.

Massachusetts. The work of building state aid roads is in the hands of the state highway commission, under whose direction plans, surveys and estimates are made. The state pays for a new right of way in case a relocation of the road is necessary. The highway commission has machinery which it loans to the local people. All contracts are let by the commission, and cities or towns may take contracts at the estimate of the commission without calling for competitive bids on the work. The inspection of the work during progress is done by the state commission.

The maximum grade allowed is 6 per cent. Width of improved surface is fixed by the state.

Connecticut. Plans, estimates and surveys are made by the state highway commission. Towns may submit competitive bids for doing the work. Contracts are let by the state highway commissioner, and inspection of the work during progress is made under his direction.

Grades and width of improved surface are fixed by the state.

Pennsylvania. The law of this state provides that all state aid highways shall be built according to the standards adopted by the state highway department. This department gives the roads thorough inspection during the period of construction. The law provides that no state aid roads shall be built less than 12 feet wide. Grades are fixed

by the state commissions. The state aid work is done under contracts let by the state highway commissioner. Counties and towns may bid on work if they so desire.

New Jersey. In this state the surveys and plans are made by the county engineer, but are subject to the approval of the state highway commissioner. The county provides the right of way for relocations. All work is done by contracts let by the county board subject to the approval of the state highway commissioner. The state inspects the roads during their construction.

Grades and width of improved surface are subject to the approval of the state commissioner.

Washington. Plans and surveys are made by the state highway commissioner. The maximum grade must not be over 5 per cent and the width of improved surface must not be less than 8 feet nor over 16 feet, unless the locality wishes to pay the whole cost of the excess width. All state aid work is done under contracts let by the state highway commissioner. Counties may bid on these contracts if they so desire. In case relocation is necessary the county provides the right of way. The county engineer inspects the roads during construction under the direction of the state highway commissioner.

Ohio. The construction of state aid roads is in charge of the state highway commissioner, who makes all plans, estimates and surveys. The width improved must not be less than 8 feet nor greater than 16 feet unless the locality wishes to pay the cost of the excess width. The grades must be such as will meet the approval of the state highway commissioner. The work is done under contracts let by the state highway commissioner, and the inspection during construction is done by him.

Michigan. Surveys for improvements to be made with state aid are made by the county, but the plans must be submitted to the state commissioner for his approval. The county or town has direct charge of the work, but the state inspects it carefully when completed. The Michigan law contains specifications according to which the roads must be constructed in order to receive state aid. All work is let by contracts by the town or county if it exceeds $500 in amount. No grades may exceed 6 per cent and the width of improved surface must not be less than 9 feet in order to receive state aid.

The work of improving state aid highways is under the supervision of the state highway commissioner. His force inspects

them while they are under construction, and makes the plans and surveys before construction is begun. Work is done under contracts which are let by the towns subject the approval of the state commissioner.

Maine.

Construction is in charge of the state board, who make all plans and surveys and let contracts and do the inspection while the road is under construction. The law provides that the roads shall not be improved for a less width than 14 feet.

Rhode Island.

PAYMENT FOR STATE AID HIGHWAYS

The state pays two-thirds of the cost in the poorer counties and one-half in the richer counties. The whole cost is paid at first by the state and the counties repay their share to the state. No part of the cost of the improvements is assessed on abutting property.

Model bill.

On county highways the state pays 50 per cent of the cost, the county 35 per cent and the town 15 per cent. On town roads the state pays from 33½ to 50 per cent and the town 66⅔ to 50 per cent, depending on whether the town is rich or poor. The county's share is paid to the contractor by the county treasurer and the state's share is paid direct to the contractor by the state treasurer. New York formerly assessed 15 per cent on abutting property owners if they originated the petition for the improvement, but this assessment has been done away with. The state does not pay any share of the cost of bridges exceeding five feet in length.

New York.

The county first pays the whole cost of the road and the state repays half the cost to the county. If the property owners force the county board to act they have to pay 10 per cent of the cost, the county 40 per cent and the state 50 per cent. All bridges on the highway to be improved are considered as part of the highway and the state pays its share of the cost. No part of the cost is assessed on abutting property except as mentioned.

Maryland.

The county treasurer pays the contractor on the certificate of the state highway commissioner. The state treasurer turns the state's allotment over to the county treasurer upon the certificate of the state highway commissioner. The state pays half of the expense of the permanent improvement and leaves it to the county to decide how much shall be borne by the county as a whole and how much assessed to the local road district. There is no provision, however, for an assessment of the cost upon the abutting property. If

Virginia.

the allotment of the state aid fund to any county is $2500 or less, that county may use it to aid in paying for the building of permanent bridges under plans made or approved by the state highway commissioner. The county must put in an equal or greater sum, however, so that the state does not pay more than half the cost of the bridges.

Massachusetts. The state treasurer pays the whole cost of the work on the order of the highway commission. The counties have six years in which to pay back to the state one-fourth of the cost. No part of the cost of the roads is assessed on the abutting property owners.

Connecticut. The state pays the full amount to the contractors and the towns afterward pay back to the state one-quarter or one-eighth of the cost, depending upon the wealth of the town. None of the cost is assessed on abutting property. Nothing is said in the law regarding aid for bridges on state aid roads.

Pennsylvania. The state pays three-quarters of the cost and the county and town each one-quarter. The total cost is first paid by the state, and the counties and towns afterward pay their share to the state treasurer. The state pays the same share of the cost in building bridges that it pays for building roads. No part of the cost of roads is assessed on abutting property.

New Jersey. The state treasurer pays one-third the cost of the roads and the county teasurer pays the contractor on the estimates of the engineer. Formerly 15 per cent was assessed on abutting property, but now no part of the cost is assessed in this way. New Jersey does not give state aid for bridges.

Washington. The state and the county each pay half of the cost of the state aid roads. Each treasurer pays direct to the contractor on vouchers of the state highway commissioner. Thirty-five per cent of the cost is paid from the county funds, and 15 per cent from the road district funds. If the property owners petition, 15 per cent is paid by the owners of all property lying within a half mile either side of the road. Nothing is said in the law about state aid for bridges.

Ohio. The state pays 25 per cent, county 50 per cent, the town 10 per cent, and abutting property owners 15 per cent. The law says nothing about state aid for bridges.

The total cost of the road is paid in the first instance by the town or county and the state afterward "rewards" them,

paying its share if the road is finished according to specifications. The rewards vary from $250 to $1000 per mile, depending on the kind of road built. No part of the cost is assessed upon the abutting property and no aid is given for the building of bridges.

Michigan.

The town pays for the cost of the roads in the first instance on the order of the state highway commissioner, and the state then pays to the town its share. This share varies from two-thirds of the cost, in poor towns, to three-sevenths of the cost in towns having a valuation of over $1,000,000. No part of the cost is assessed on abutting property, and nothing is said in the law about state aid for bridges.

Maine.

Rhode Island. The cost of the roads is entirely paid by the state.

MAINTENANCE OF STATE AID HIGHWAYS

The state engineer has charge of the maintenance of state aid highways. The county reimburses the state one-third or one-half the cost of maintenance according to whether the county is poor or rich.

Model bill.

The maintenance of all roads built with state aid is under the direct regulation of the commission. The commission is directed to provide a system of patrol of state highways so that each section may be under constant supervision. The state pays the cost of the maintenance in the first instance, and each town in which a state aid road lies repays $50 a year to the state for each mile. The town superintendents of highways carry out the work of maintenance under the direction of the commission.

New York.

The county boards must maintain the state aid highways at county expense. If they are not maintained in a manner satisfactory to the state engineer no further state aid is granted to the county.

Maryland.

Virginia. The state commissioner has charge of the maintenance of state aid highways.

The maintenance of state aid roads is in the hands of the highway commission. They must contract with towns to maintain the roads properly. Each town pays $50 per mile per annum for maintaining the state aid roads and the remainder is paid by the state. The expense of snow removal is borne by the town alone.

Massachusetts.

The maintenance of state aid highways is in the hands of

the state highway commissioner and the state pays the whole cost at first. The towns reimburse the state one-fourth the cost of maintaining their roads. **Connecticut.**

The towns are charged with the maintenance of the state aid roads and pay only one-fourth of the cost. The state pays three-fourths of the cost and if the roads are not properly maintained the state commissioner may take the work out of the hands of the town, in which case the town must pay 25 per cent of the cost to the state. **Pennsylvania.**

The county highway engineer is charged with keeping the state aid roads in good condition, and the expense is all borne by the county. If the roads are not maintained in a manner satisfactory to the state highway commissioner he is instructed by law to refuse any further petitions for state aid from that county until the roads are repaired in an acceptable manner. **New Jersey.**

The state aid roads are maintained at county expense by the supervisors of the districts through which they pass. These supervisors act under the direction of the state highway commissioner. **Washington.**

State aid roads must be maintained by the counties at their own expense. **Ohio.**

State aid roads must be maintained by the county or town petitioning for their construction. If they are not properly maintained the state commissioner does not grant any further state aid to them. **Michigan.**

Towns must maintain state aid roads at their own expense to the satisfaction of the state highway commissioner. **Maine.**

The state maintains all roads built by the state and charges none of the cost to the locality excepting that the town must keep the roads free from snow. **Rhode Island.**

CONVICT LABOR ON ROADS.

Connected with an active interest on the part of the state in road building one feature that always attracts a great deal of attention is the possibility of employing the state convicts in either preparing the material or in actually constructing the roads. A number of the southern states have had very good success in using gangs of convicts to construct the state roads. Almost every highway commissioner from the north-

ern states who has examined into the practical operation of this system in the south has returned with the opinion that it would not be readily adaptable to northern conditions. A large percentage of the convicts in the south are negroes in prison for petty offenses, and very good results have been obtained in using gangs of them in road work. No northern state, in which the convicts are almost all white men, has ever attempted, on any large scale, to use their convicts in this manner.

The only northern state that has used its convicts to any extent in road construction is Illinois. In that state they have adopted the plan of establishing stone-crushing plants at the two penitentiaries. The stone produced at these plants is given by the state without charge to the towns or counties desiring to use it, under the restriction that it must be used according to the directions of the state highway commission.

EXCERPTS FROM SPECIFICATIONS USED IN CONSTRUCTING STATE AID ROADS IN MASSACHUSETTS, NEW JERSEY, NEW YORK, CONNECTICUT, PENNSYLVANIA, AND MARYLAND.*

MASSACHUSETTS

EARTHWORK

The roadbed shall be graded for the width of ——— true to the lines and grades given by the engineer and in conformity with the plans, profiles, and cross-sections furnished by the commissioners, and so shaped that after the broken stone is rolled in place the surface of the roadway shall have a crown of three-quarters of an inch to the foot.

All clay and spongy material shall be removed to a depth to be determined by the engineer, and the space thus made shall be filled with such material as the engineer may direct.

In general, embankments will be made from material from within the location of the road, as will also all filling and grading, but there if is not sufficient suitable material in the excavation, in the opinion of the engineer, the contractor shall find such material outside of the highway location. Such material will be classed as borrow.

Embankments shall be formed of successive layers of not more than

* Abstracted from Office of Public Roads Bulletin No. 29, June, 1907.

twelve (12) inches in thickness, each layer to be thoroughly rolled by a roller weighing not less than two tons.

All trees, stumps, and roots within the roadbed and on slopes shall be grubbed up and removed as the engineer may direct, without additional compensation.

Ditches of such width and depth as the engineer may direct shall be excavated by the contractor wherever the engineer may order them, at the contract price for excavation.

All surfaces in slopes or on embankments, whether old or new, shall be left with neat and even surfaces according to the lines, grades, and directions given by the engineer, without additional compensation.

All measurements of earthwork shall be made in excavation.

Material obtained from excavation within the limits of the location and used in embankments, or for any other purpose, will be paid for as excavation only.

Allowance for culvert excavation will include only one (1) foot outside of the masonry sections, as shown on plans.

Borrow

When, in the opinion of the engineer, there is not sufficient suitable material within the limits of the highway location of the section under contract, to form the necessary embankments, or for subgrading, or for shoulders, the contractor shall obtain such material from outside the highway location. This material shall be known as borrow, and may be of any quality satisfactory to the engineer for the purpose for which it is required.

If found within a radius of one thousand (1000) feet from any point on said section under contract it will be paid for at the borrow price.

If, however, in the opinion of the engineer, no suitable material can be obtained within the limit just described, the contractor shall find satisfactory material at a greater distance. In this event, in addition to the regular borrow price, the sum of one-half (½) cent per cubic yard for each one hundred (100) feet of overhaul shall be allowed him for all material so supplied, the length of haul to be measured from the pit along the shortest available route to the one thousand (1000) foot limit above described.

Borrow pits will be cross-sectioned and all quantities will be measured in the pits.

Ledge Excavation

Only such ledge as requires blasting for its removal, and boulders of one-half (½) a cubic yard or more in volume, will be estimated as ledge excavation.

No allowance for ledge excavation in the roadbed shall be made outside of or for more than twelve (12) inches below the lines indicated on the

cross-sections showing the finished surface, the side slopes to be one-fourth (¼) to one (1).

Allowance for ledge in drains will be made on the basis of a width of trench of two (2) feet and a depth of four (4) inches below the invert of the pipe; allowance for ledge in gutters will be made on the basis of the width of the gutter and (12) inches in depth below the proposed surface.

Culverts

Reinforced Portland cement-concrete culverts shall be constructed where ordered by the engineer to the lines and grades given by him.

Culvert ends shall be laid parallel to the center line of the roadway. All culvert masonry shall be measured in accordance with the dimensions shown on the plans.

No allowance shall be made for cofferdams, pumps, labor, etc., which may be necessary on account of water.

Portland Cement Concrete Masonry

The concrete shall be composed of broken stone or screened gravel, and sand—all of which shall be clean, hard, durable, sharp, and free from clay, dirt, and other objectionable material—Portland cement and fresh, clean water.

To each part of Portland cement there shall be by volume two (2) parts of sand and five (5) parts of broken stone or srceened gravel, and such a proportion of water as the engineer may from time to time determine.

The broken stones or gravel stones shall be of the following sizes:

For all work less than six (6) inches in thickness the stones may vary in their longest dimension from one-quarter (¼) of an inch to three-quarters (¾) of an inch; between six (6) inches and twelve (12) inches, from one-quarter (¼) of an inch to one and one-quarter (1¼) inches; more than twelve (12) inches in thickness, from one-quarter (¼) inch to two and one-half (2½) inches.

The cement and sand shall first be thoroughly mixed dry, in the proportions specified, in proper boxes. Clean water shall then be added and the materials thoroughly mixed. The broken stone, previously drenched with water, shall then be deposited in this mixture and the ingredients thoroughly mingled and turned over until each stone is covered with mortar. The batch shall then be carefully deposited without delay and thoroughly rammed in layers not more than six (6) inches in depth until the water flushes to the surface and all the voids are filled.

The concrete shall not be allowed to fall from any considerable height.

Before the concrete is placed in the moulds, a sheet-iron plate, six or eight inches in width and about six feet long, or of such other dimensions as the contractor may find convenient, shall be held in position one and

one-half ($1\frac{1}{2}$) inches from the surface of the mould or form. The space between the form and this separator shall be filled with mortar, composed of one part of Portland cement and one part of sand, mixed to such a consistency as the engineer may direct, and, if he shall so direct, the mortar shall be thoroughly spaded after it is placed. Only a small batch shall be mixed at a time, and then only as needed. Immediately after the space between the separator and the form is filled with mortar the ordinary concrete shall be placed behind the separator, the separator removed, and the backing and facing thoroughly rammed together to a close bond. No delay shall be permitted in placing the concrete backing, and both the facing and the backing shall be done as nearly simultaneously as is possible.

Should voids be discovered when the forms are taken down, the defective work is to be removed and the space refilled with one to one cement mortar. The exposed surfaces shall be smoothed over with a neat Portland cement grout, laid on with a brush, until a smooth surface is secured.

Centers and forms, satisfactory to the engineer, shall be provided by the contractor. They shall be made of planed lumber and shall fit the curves and shapes of the work. The sheathing shall be laid tight and shall be made clean before using.

The centers shall be true to the lines, satisfactorily supported and firmly secured, and shall remain in place as long as the engineer may direct, and shall be replaced by new ones when they lose their proper dimensions or shape.

In connecting concrete already set with new concrete, the surface shall be cleaned and roughened and mopped with a mortar composed of one part Portland cement and one part sand.

When work is done under such conditions that the mortar is liable to freeze, the contractor shall provide the necessary means for and shall thoroughly heat all materials, and also the water, and shall thoroughly protect the masonry from damage by rain and frost during and after laying.

During warm and dry weather, and whenever the engineer may direct all newly built concrete shall be kept well shaded from the sun and well sprinkled with water until set.

In laying concrete under water the concrete shall not fall from any considerable height, but be deposited in the allotted place in a compact mass. The concrete must not be rammed, but leveled with a rake or other suitable tool immediately after being deposited. No concrete shall be laid in running water.

Expanded metal or twisted rods, to be furnished to the contractor by the commission, shall be imbedded in the concrete by the contractor as directed by the engineer, without extra compensation.

No back-filling or loading whatever shall be placed on or against the concrete masonry until ordered by the engineer.

The Massachusetts highway commission will furnish all cement to be used in this work and will deliver it to the contractor at the nearest railroad freight station. The contractor shall, at his own expense, team the cement to the work and store it, and protect it from the weather to the satisfaction of the engineer.

The price to be paid per cubic yard for concrete masonry shall include the back-filling and all necessary centers and forms, and all work on the same, and no allowance shall be made for cofferdams, pumping or bailing, or for any materials or labor necessary on account of water.

All concrete shall be measured in accordance with the dimensions shown on plans.

Shaping Surface for Broken Stone

Before the broken stone is spread the roadbed shall be shaped to a true surface, conforming to the proposed cross-section of the highway and rolled by a steam roller, unless otherwise ordered by the engineer. All depressions occurring must be filled with suitable material and again rolled, until the surface is smooth and hard, the width to be paid for to include only the width of broken stone.

Broken Stone

Broken stone, consisting of ———, shall be spread and rolled on the roadbed prepared as hereinbefore described, as follows:

The width of the broken stone shall be ——— (—) feet.

All broken stone used shall be laid in layers or courses. The bottom course shall consist of stones from one and one-quarter ($1\frac{1}{4}$) inches to two and one-half ($2\frac{1}{2}$) inches in their longest dimension; the upper course of stone from one-half ($\frac{1}{2}$) inch to one and one-quarter ($1\frac{1}{4}$) inches in their longest dimension.

The bottom course shall be ——— (—) inches deep at the center and ——— (—) inches deep at the sides after rolling. The top course shall be ——— (—) inches deep at the center and ——— (—) inches deep at the sides after rolling.

After the two courses above described are thoroughly compacted, broken-stone screening shall be laid on, watered, and rolled until the mud flushes to the surface. The screenings so used shall not be larger than will pass through a half-inch mesh and shall contain all the dust. Care must be taken to lay on only enough of the screenings to cover the larger stones.

Each course, bottom, top, and binder shall be rolled separately by a steam roller and evened up with material of the same size and quality as has been used in that particular course, and to the satisfaction of the engineer.

All broken stone shall be spread from the carts by hand, or from a dumping board, of from self-spreading carts.

No soft or disintegrated stone shall be used.

If so ordered by the engineer the thickness of the broken stone shall be increased or diminished at such points as he may direct.

The grade of the finished surface of the road shall present a crown of three-quarters (¾) of an inch to the foot.

If local stone or stone not shipped by rail is used, it shall be weighed on scales furnished by and at the expense of the contractor. Said scales shall be satisfactory to the engineer and they shall be sealed at the expense of the contractor as often as the engineer may deem necessary to insure their accuracy.

A sworn weigher, to be appointed and compensated by the Massachusetts highway commission, shall weigh all broken stone required to be weighed as above provided.

If the stone is shipped by rail the car weights will be accepted.

Vitrified Clay Pipe and Iron Water Pipe (for Culverts)

Vitrified clay pipe and iron water pipe shall be furnished and laid where directed by the engineer.

All clay pipe shall be of first quality, salt glazed, free from blisters and cracks, straight and round. If eighteen (18) inches or more in diameter the pipe shall be "double strength," or if ordered by the engineer, ordinary pipe may be used and laid in concrete, which shall be tamped about the pipe to the satisfaction of the engineer. If, however, concrete is used it shall be paid for at the regular price for concrete.

All iron pipe shall be of the best quality of water pipe and free from imperfections of any kind.

All pipe shall be laid true to the lines and grades furnished by the engineer. Nothing but selected fine material, free from large stones, shall be placed around and under the pipe, and all material placed under and about the pipe shall be thoroughly tamped in place by a thin iron tamping bar. All joints shall be made of first quality natural cement mortar, mixed in proportion of one (1) part cement to one (1) part of clean, sharp sand, carefully filled in all around the pipe. The ends of pipe drains used as culverts must be protected by concrete masonry or concrete walls. The price per foot paid for pipe laid as above includes the cost of trenching and back-filling, and all incidental work except the masonry ends; *provided, however,* that when the depth of the trench exceeds five (5) feet all excavation necessary on account of additional depth shall be paid for by the cubic yard at the regular contract price for excavation.

Guard Rail

Fencing shall be placed on edges of embankments and at such other places along the road as the engineer may deem necessary. It shall be of the section shown on plan; the posts shall be of well-seasoned, straight, sound chestnut or cedar, not less than six (6) inches in diameter, spaced eight (8) feet apart on centers, the bottom of each post to be sawed off square and set plumb in straight lines, three (3) feet into the ground and three and one-half (3½) feet above the ground, and the back-filling thoroughly tamped. All bark shall be removed before setting, all knots hewn down to face and the exposed surfaces shaved. The top rails shall be four (4) inches square and the side rails of two by six (2×6) inch well-seasoned, straight-grained spruce, or other wood satisfactory to the engineer, planed, free from loose or unsound knots, and both top and side rail shall be notched into and securely fastened to the posts, as shown in the plan, and be long enough to extend over three (3) posts and break joints.

All parts of the exposed surface of the fence shall be painted with one coat of white lead and linseed oil.

At culverts square iron posts, one and one-quarter (1¼) inches square, shall be used, set into the coping stone at least four (4) inches, and leaded. The side rail shall be bolted to the iron posts with two bolts set in holes drilled through each post.

Side Drains

Drains will be built where directed by the engineer.

All drains must be carried to an outlet approved by the engineer.

The drain trench shall be excavated to a width of twelve (12) inches at the bottom and fifteen (15) inches at the top, and shall be excavated only as fast as the drain can be finished.

When the grade of the finished road is three (3) inches or more to the hundred (100) feet, the bottom of the drain trench must be three and one-half (3½) feet below the finished surface of the road at that part of the cross-section.

On the bottom of this trench shall be placed two (2) inches of gravel or broken stone which will pass through a one and one-quarter (1¼) inch mesh, and not through a half (½) inch mesh.

On this material shall be laid a five (5) inch salt-glazed vitrified clay pipe, with bell and spigot joints, unless otherwise ordered, with open joints, and the bell ends toward the rising grade.

All pipe must be laid true to a line and grade, and no pipe is to be laid on a grade of less than three (3) inches in one hundred (100) feet.

Gravel or broken stone of the sizes already described shall be filled about the pipe and over it for a depth of one (1) foot. This must be carefully tamped about and rammed over the pipe. The remainder of

the trench is to be filled with stone which will pass through a three (3) inch and not through a one (1) inch mesh, and this material shall be thoroughly tamped. Any sand, silt, or earth getting into the pipe or the interstices of the stone in the trench must be removed by the contractor at his own cost, even if it be necessary to rebuild the drain.

Where, in the opinion of the engineer, it is necessary to extend a drain to an outlet beyond the section needing to be drained, the pipe will be laid with cement joints, true to line and grade, and the gravel or stone in the trench omitted, the trench being back-filled with the material excavated from the same.

Where a pipe is carried through a bank the outlet must be protected by masonry, as provided in pipe culverts.

The price per lineal foot includes the cost of trenching and refilling with gravel or broken stone, the cost of the pipe and laying, as well as all incidental work.

No allowance will be made for pipe larger than above specified laid in any drain unless the larger pipe has been ordered in writing by the engineer.

Stone Filling

At such places as the engineer may direct, stone filling shall be placed. Excavations shall be made to the lines shown on the cross-sections. The stones may be either wall stones or cobbles ranging in size from the smallest obtainable to those not exceeding eight (8) inches in their longest dimension, and the larger stones shall be placed at the bottom.

The excavation will be paid for at the regular price for excavation.

The stone filling will be measured according to the original cross-sections, without allowance for shrinkage or settlement, and paid for by the cubic yard.

Catch Basins

Catch basins will be built of brick masonry or Portland cement concrete, as shown on plan and in accordance with the directions of the engineer.

All bricks used shall be well formed and hard burnt and shall be well soaked in water before laying.

The joints shall be thoroughly flushed full of mortar, consisting of one part of natural cement of the best quality and two parts of coarse, clean, sharp sand, free from loam and pebbles.

No joint on the face shall be greater than one-quarter inch.

After the bricks are laid the joints shall be neatly pointed on the inside.

As the walls are laid up they shall be well plastered with mortar on the outside.

The contractor is to furnish all labor, tools, and materials necessary for the basins, excepting the frames and grates, which will be furnished

by the commission, and delivered at the railroad freight station nearest to the site of the work. The price paid for each basin will include all excavation, back-filling, and incidental work.

Cobble-Stone Gutters

Paved gutters will be built where directed by the engineer, the same to be laid by journeymen pavers.

No gutter is to be laid until after the broken stone has been rolled, unless otherwise ordered by the engineer.

In no case is the roller to pass over any part of any paved gutter.

Gutters not exceeding four hundred (400) feet in length shall be three (3) feet wide with a shoulder one (1) foot wide and a dish of three (3) inches.

Gutters exceeding four hundred (400) feet in length shall increase the dish above this length at the rate of one (1) inch to each three hundred (300) feet.

All stone used in gutters shall be rounded field, bank, or river stone; no flat, shaky, or rotten stone shall be used.

The stone may, on the average, lay from four (4) to six (6) square yards to the ton. A cubic yard may be estimated to weigh one and one-third (1⅓) tons.

The larger selected stone will be laid in the gutter row and on the edges to a true line and grade, with the largest diameters lengthwise of the road. All other stone will be laid with the longest diameters across the gutter.

The trench shall be excavated to a depth of twelve (12) inches below the finished grade of the gutter; gravel shall then be spread and rammed to a depth of four (4) inches. A layer of bedding sand, or gravel free from stone larger than one-half (½) inch in diameter, shall then be spread of a sufficient thickness to bring the gutter stone which are bedded in it to the proper grade and cross-section after they are thoroughly rammed.

Each stone is to be rammed to an unyielding foundation. The contractor shall employ one rammer to every two pavers. The surface shall then be covered with coarse sand or fine screened gravel free from clay or dirt, which must be well broomed into all joints. The stone shall then be rerammed and the surface left smooth and even. If from any cause the stone in a gutter shall have been disturbed and left uneven, they must be relaid by the contractor and at his cost. Sand or screened gravel shall then be spread over the entire surface of sufficient depth to fill all interstices.

The edge of the gutter toward the road shall be left one-quarter (¼) inch below the surface of the adjoining broken stone; in no case must it project above it.

All broken stone which may be disturbed during the paving of the gutter must be carefully replaced and thoroughly rammed.

The bank on the outside of the gutter must be sloped to the gutter, so as to have no bunches or depressions on its surface.

NEW JERSEY

Subfoundations

When the excavations and embankments have been brought to a proper depth below the intended surface of the roadway, the cross-section thereof conforming in every respect to the cross-section of the road when finished, the same shall be rolled with a —— ton roller until it is ——— inches below the intended surface of the road and is approved by the engineer and supervisor. If any depressions form under such rolling, owing to improper material or vegetable matter, the same shall be removed and good earth substituted, and the whole rerolled until thoroughly solid and to above-mentioned grade. Water must be applied in advance of the roller when, in the opinion of the engineer and supervisor, it is necessary.

Stone Construction

TELFORD FOUNDATIONS

After the roadbed has been formed and rolled, as above specified, and has passed the inspection of the engineer and supervisor, a bottom course of stone, of an average depth of —— inches, is to be set by hand as a close, firm pavement, the stones to be placed on their broadest edges lengthwise across the road in such manner as to break joints as much as possible, the breadth of the upper edge not to exceed four (4) inches. The interstices are then to be filled with stone chips, firmly wedged by hand with a hammer, and projecting points broken off. No stone of greater length than ten (10) inches or width of four (4) inches shall be used, except each alternate stone on outer edge, which shall be double the length of the others and well tied into the bed of the road. All stones with a flat, smooth surface must be broken. The whole surface of this pavement must be subjected to a thorough settling or ramming with heavy sledgehammers, and thoroughly rolled with a —— ton ——— roller. No stone larger than two and one-half (2½) inches shall be left loose on top of telford.

Macadam

FIRST COURSE OF BROKEN STONE

After the roadbed has been formed and rolled, as above specified, and has passed the inspection of the engineer and supervisor, the first layer of broken stone, consisting of two and one-half (2½) inch stone, or stone that will pass through a ring three (3) inches in diameter, shall be deposited in a uniform layer, having a depth of —— inches, and rolled repeatedly with a —— ton ——— roller until compacted to the satisfaction of the engineer and supervisor. No stone in this course shall be less than two (2) inches in length.

The depth of loose stone in this and all other courses must be measured by blocks the required thickness of the said loose stone. These blocks must be placed at frequent intervals amid the loose stone when being spread.

Binder between First and Second Course for Telford or Macadam.

On the first course of stone a quantity of ——— binder shall be spread in a uniform layer, and the whole rolled until the stones cease to sink or creep in front of the roller. The quantity and quality of this and all other binding shall be subject to the approval of the engineer and supervisor. Water must be applied in advance of the roller, if ordered by the engineer or supervisor.

Second Course of Broken Stone for Macadam or Telford

The second course of broken stone shall consist of one and one-half (1½) inch stone; that is, every piece of stone shall be broken so that it can be passed through a ring two (2) inches in diameter, and no stone shall be more than two (2) inches or less than one (1) inch long. This course shall be spread in a uniform layer —— inches in depth and rolled until thoroughly settled into place to the satisfaction of the engineer and supervisor. Water must be applied as ordered by the engineer or supervisor.

Binder on Second Course of Stone

Binder on this course of stone must be applied in the same manner as binder on first course of stone, as directed by engineer and supervisor.

Surface

When the two courses are rolled to the satisfaction of the engineer and supervisor, a coat of fifty (50) per cent of three-quarters (¾) inch stone and fifty (50) per cent of screenings, properly mixed, is to be spread of sufficient thickness to make a smooth and uniform surface to the road, then again rolled until the road becomes thoroughly consolidated, hard and smooth.

Rolling must be done by the contractor with a —— ton ——— roller, approved by the engineer.

Any depressions formed during the rolling, or from any other cause, are to be filled with one and one-half (1½) inch stone, or three-quarter (¾) inch stone, or both, and screenings, approved by the engineer, and the roadway brought to the proper grade and curvature as determined by him.

Water must be applied in such quantities and in such manner as directed by the engineer or supervisor.

Manner of Rolling

In the rolling the roller must start from the side lines of the stone bed and work toward the center, unless otherwise directed. The rolling shall at all times be subject to the directions of the engineer and supervisor, who may, from time to time, direct such methods of procedure as in their opinion the necessities of the case may require.

Quality of Material

All stone must be as nearly cubical as possible, broken with the most approved modern stone-crushing machinery, free from all screenings, earth, and other objectionable substances, of uniform size, and the same kind and quality, or as good in every particular, as that shown in the engineer's office. The one and one-half (1½) inch stone, three-quarter (¾) inch and screenings for binder and final finish must be of the best trap rock, free from loam or clay.

The contractor must furnish samples to the engineer of the kind of stone to be used in the work before the opening of the bids, and to the state commissioner of public roads before the approval of the contract by him.

Entrances to Dwellings

All driveways leading to dwellings along the road shall be macadamized with the second course and finished in the same manner as prescribed for the main road. The macadamizing shall be carried to a distance of not more than six feet beyond the gutter line of the road, as indicated by the engineer's stakes, but in no case shall the macadamizing be carried beyond the side line of the road as indicated by the fences.

Shouldering

A shoulder of firm earth or gravel is to be left or made on each side, extending at the same grade and curvature of road to side ditches or gutters. This shoulder is to be rolled according to the directions of the engineer.

NEW YORK

Rolling Subgrade

After the surface of the subgrade has been properly shaped, and before any broken stone or other material is put on, it shall be thoroughly rolled and compacted. This rolling shall be done with a steam road roller weighing approximately ten tons, and so built that its wheels shall cover when rolling the entire width of its track. The roller must be of a kind approved by the state engineer. All hollows and depressions which

develop during the rolling shall be filled with material acceptable to the engineer and the subgrade shall again be rolled. This process of filling and rolling shall be repeated until no depressions develop. The shoulders also shall be rolled in the same manner, but in places where the character of the material makes the use of a ten-ton roller impracticable a lighter roller shall be used.

In places where the material of the subgrade or of the shoulders is unstable, and will not consolidate under the action of the roller, and is so great in extent that its removal is impracticable, it shall be formed to the desired shape and treated in such manner as may be necessary to consolidate and compact it, and to give the best results in providing a stable foundation for the entire roadway.

The expense of all such special work shall be borne by the contractor and must be considered by him in making his proposal.

The bottom course shall not be placed on any subgrade until the subgrade has been accepted by the engineer.

Surface of Roadway

The surface of the roadway shall be formed of broken stone macadam or any other material shown on the plans or ordered by the state engineer. When formed of broken stone macadam it shall have the thickness shown on the plans. In general it will be formed of three courses—a bottom course three inches thick after being rolled, a middle course two or three inches thick after being rolled, and a top course one inch thick after being rolled.

Broken Stone Macadam

Where shown on plans, called for in the specifications, or ordered by the state engineer, at prices named in the supplementary bidding sheet, broken stone macadam shall be placed in accordance with the specifications.

Broken Stone

The contractor shall submit with his bid a written statement of the quarries, ledges, or other sources of supply from which he proposes to obtain the stone for the road. If the proposed quarries are thoroughly developed and a uniform product, satisfactory to the state engineer, can be obtained from them, this will be accepted and the contractor will be so informed. If after trial it is found that partially developed quarries, ledges, or other sources of supply do not furnish a uniform product, of if for any reason the product from any source at any time proves to be unsatisfactory to the state engineer, he may decline to continue its use and can require the development of other quarries, or he may require the contractor to furnish other sources of supply, and the

contractor shall have no claim for increased payment on account of such requirement. Immediately after the crusher is in operation the contractor shall furnish to the engineer in charge a sample consisting of about $\frac{1}{2}$ of a cubic foot of each size of the crushed stone to be used, showing character and size. If the character and size of the stone submitted are satisfactory to the state engineer and are accepted by him, the samples will be retained by the engineer, and all stone which are inferior in character or size to these samples will be rejected.

Quality of Broken Stone

Broken stone and screenings must be of a hard and compact texture and of a uniform grain. The fragments shall have rough surfaces such as are obtained by fracture. Water-worn pebbles will not be accepted. Disintegrated and rotten stone from the surface of a quarry or elsewhere will not be accepted. All stone shall be thoroughly clean before crushing and must be well screened and free from injurious matter of every nature.

The broken stone shall be spread in three courses when the top course is built of trap rock, granite, gneiss, or any of the harder grades of stone; in two courses when the top course is built of limestone or any of the softer grades of stone. The number of courses shall be as shown on the plans or ordered by the engineer.

Bottom Course

The bottom course, in either case, after it is rolled shall have the thickness shown on the plans or indicated on the quantity sheet, and may consist of approved trap rock, granite, gneiss, or any of the harder grades of limestone or tough sandstone ——— broken in fragments that will pass through a three-inch circular ring but will not pass through a two-inch circular ring.

When local stone is crushed to form the bottom course only, all fragments that will pass through a three-inch circular ring but will not pass through a one-half inch circular ring may be used. Care must be taken to distribute evenly the smaller stone among the larger stone.

Filler for Bottom Course

The filler for the bottom course shall be either screenings or sand. Screenings shall consist of fragments of the kind and quality of stone specified, that will pass through a one-half-inch circular ring. They shall be free from any injurious material and shall contain all the dust of fracture. If sand is used, it shall not be excessively fine and must be satisfactory to the engineer.

Middle Course

When the road is built in three courses, the middle course after it is rolled shall have the required thickness shown on the plans or indicated on the quantity sheet, and shall consist of ——— broken into fragments that will pass through a two-inch circular ring but will not pass through a one-inch circular ring.

Top Course

When the road is built in three courses the top course after it is rolled shall have the required thickness shown on the plans or indicated on the quantity sheet, and shall consist of ——— broken in fragments that will pass through a one-inch circular ring but will not pass through a one-half inch circular ring.

When the road is built in two courses the top course after it is rolled shall have the required thickness shown on the plans or indicated on the quantity sheet, and shall consist of limestone ——— broken in fragments that will pass through a two-inch circular ring but will not pass through a one-half inch circular ring. Care must be taken to distribute the smaller stone evenly among the larger stone.

Binder for Middle and Top Courses

Screenings for binder for middle and top courses shall consist of fragments of the kind and quality of stone specified, that will pass through a one-half inch circular ring. They shall be free from any injurious material and shall contain all the dust of fracture.

Sprinkler

The sprinkler shall be built without a reach to allow short turns. The tires on the wheels shall be at least six inches wide and the axles shall be of unequal length, so that the front and rear wheels will not roll in the same track.

Spreading and Rolling

After the subgrade has been prepared and has been accepted by the engineer, a layer of broken stone of the approved size and quality for bottom course shall be spread evenly over it to such depth that it shall have, when rolled, the required thickness. The depth of the loose stone shall be fixed by laying upon the subgrade cubical blocks of wood of the required size (1⅓ times thickness of course to be formed) and spreading the stone evenly to the same thickness.

The roller shall be run along the edge of the stone backward and forward several times on each side before rolling the center. Before put-

ting on the filler the bottom course shall be rolled until the stones do not creep or weave ahead of the roller. In no case shall the screenings or sand for filler be dumped in mass upon the crushed stone, but they shall be spread uniformly over the surface from wagons or from piles that have been placed on the shoulders. It shall then be swept with rattan or steel brooms and rolled dry. This process shall be continued until no more will go in dry, when the surface shall, if required by the engineer, be sprinkled, to more effectually fill the voids. No filler shall be left on the surface.

The middle course of stone shall be spread on the bottom course to such a depth that it shall have, when rolled, the required thickness. Blocks of wood (1½ times thickness of course to be formed) shall be used to fix the depth of the loose stone; care shall be taken to preserve the grade and crown. Before putting on the screenings it shall be rolled dry until the stones do not creep or weave ahead of the roller. It shall then be filled with screenings, leaving none on the top, and rolled dry.

The top course of stone shall be spread on the middle course to such a depth that it shall have, when rolled, the required thickness. Blocks of wood (1½ times thickness of course to be formed) shall be used to fix the depth of the loose stone; care must be taken to preserve the grade and crown, also to prevent a wavy surface. It shall then be covered with dry screenings, swept and rolled dry, after which the road shall be sprinkled until saturated, the sprinkler being followed by the roller. More screenings shall be added, if necessary, and the sweeping, sprinkling, and rolling shall continue until a grout has been formed of the screenings, stone dust, and water that shall fill all the voids and shall form a wave before the wheels of the roller. The road shall be puddled as many times as may be necessary to secure satisfactory results.

After the wave of grout has been produced over the whole section of the road, this portion of the road shall be left to dry, after which it shall be opened to travel. Where necessary, enough screenings or approved sand shall be spread on top of the macadam to leave a wearing surface at least three-eighths of an inch thick. This wearing surface shall be maintained and renewed, if necessary, until the whole road has been accepted.

Method of Carrying on the Work

All work shall be carried along together where practicable. The stone shall be rolled and promptly filled after being spread, and travel upon loose stone shall not be permitted.

No extra allowance will be made for material driven into the subgrade by the roller, wagons, or by other means, or for any mistake made by the contractor in preparing subgrade. Lighter rollers, rammers, or other suitable implements shall be substituted for the ten-ton steam roller, if the engineer so directs.

Before a road will be finally accepted the macadam surface must be firm, hard, smooth, regular, well bound, and must be covered with a proper wearing surface. The shoulders must be well formed and the ditches clear. The spoil-banks, borrow-pits, and all slopes along the roadsides must be left in regular form. All waste materials must be removed and the whole put in a neat and workmanlike condition.

CONNECTICUT

Kind of Stone

Unless otherwise specified, trap rock will be required.

Courses of Stone

There shall be two courses of broken stones under finishing course; first course to be 4 inches, and second course to be 2 inches over all when rolled; no allowance to be made for settling.

Dimensions of Broken Stone

The stone for the first course shall be from $\frac{3}{4}$ of an inch to 2 inches longest diameter, mixed in the screens (not in the bins), the smaller sizes to predominate. Stone for the second course shall be from 1 inch to $1\frac{1}{2}$ inches longest diameter. No tailings shall be used in either course.

First and Second Courses

The stone shall be dumped on the side of the road where it is possible; if not, it can be dumped on the side of the roadbed and scattered with shovels; the reason for this is that the stone will have a uniform pressure in rolling. If a patent spreading wagon is used by the contractor, it will not be necessary to dump the stone, but it can be spread by the wagon. After stone has been spread for the first course, sufficient to roll down to 4 inches, a roller shall be run over the stones a sufficient number of times to make this course solid and firm. after which the second course of 2 inches shall be applied in the same manner as specified for the first course, and also receive the same roller treatment. If in the putting on of either course any settling is found, all such places must be brought up to grade level before any other course is commenced. In the rolling of these courses the roller work must be continued until the broken stone settles down into a firm and compact condition.

Finishing Course

This course shall be 1 inch thick when finished. Trap rock screenings, including dust (no screenings larger than $\frac{1}{2}$-inch stone will be allowed), shall be used as a finishing course. The screenings (after the

rolling has been done on the last course of broken stone) shall be carted on the sides of the road proper and dumped at suitable intervals, after which all wheel tracks and foot-marks of horses shall be carefully filled and then rolled down firmly. Then the screenings shall be scattered dry over the surface so as to fill all interstices, and the roller shall be run over the surface to shake in the dust. Immediately after, a sprinkling cart shall be used and the screenings washed in, after which more screenings must be added and sprinkled and rolled again, and the screenings, sprinkling, and rolling must be continued until all the coarse stones have been covered and interstices completely filled and the road is firm and smooth and will shed water and measure in depth 1 inch of screenings for wearing surface. The contractor will not be allowed to put on the screenings all at one time, but must spread them on as described above, and will not be allowed to deviate from the above treatment in any way. The contractor must not wet the screenings before they have been scattered on the broken stone, and, furthermore, they must be perfectly dry before they are put on the road.

PENNSYLVANIA

Roadbed

The graded roadbed must be rolled until firm with a steam roller weighing not less than 16,000 pounds nor more than 20,000 pounds. Any depressions formed under such rolling must be filled and rolled again until the subgrade presents a uniform appearance and is identical in form with the cross-section of the road when finished. Under no circumstances must stone be laid until the subgrade has been thoroughly rolled to the satisfaction of the engineer or inspector in charge.

Macadam

Only good solid stone shall be used in macadamizing. Bidders will name the kind of stone they propose using in said work, and also its location, unless the kind of stone required to be furnished is mentioned in the specifications. On the prepared roadbed shall be placed the bottom course, extending ——— feet on each side of the center line, and composed of crushed stone not larger than will pass through a 3-inch ring in all directions nor smaller than 1½-inch size. After being evenly spread the course shall be thoroughly rolled with the roller hereinbefore specified until none of the stone moves under the roller. All material must be added dry, but water must be applied ahead of the roller. The bottom course must be ——— inches deep.

Telford Macadam

Only good solid stone shall be used in telford construction. Bidders will name the kind of stone they propose using in said work, and also its location, unless the kind of stone required to be furnished is mentioned in the specifications. On the proposed roadbed shall be placed the bottom course, extending ——— feet on each side of the center line, the stones composing the course to be 9 to 12 inches long by 3 to 5 inches wide and ——— inches deep, placed vertically by hand on their broadest edges. Stones are to be laid in lengthwise courses across the road, and all interstices filled with broken stone wedged with a hammer. All projecting points must be broken off to bring the surface of the stone true to grade, the course to be thoroughly rolled with the roller hereinbefore specified until the stone does not rock under the roller. Good hard native stone can be used for the telford course.

After completion of the bottom course, the second course, to be ——— inches deep, shall be applied, of crushed stone not larger than will pass through a 1½-inch ring in all directions, nor smaller than ¾-inch size, and rolled as previously directed until firm and solid, water being applied ahead of the roller.

The finishing course shall be 1 inch thick, of the same material as the second course and composed of rock screenings, at least 50 per cent of which must be of sizes from ½ inch to ¼ inch. It shall be applied dry and rolled once before wetting, then alternate applications of water and rolling until finally completed, when the surface must present a uniform appearance and conform to the shape and grade fixed by these specifications and the accompanying plans.

The several courses of materials used in the construction of the road must each be of the required depth after rolling (allowance for compression should be at least one-half).

Trap rock or good hard blue limestone must be used for the second and top courses.

The rolling must be done with the utmost thoroughness in each of the courses. In all rolling the roller must start from the side lines of the roadbed and work toward the center. The contractor shall sprinkle and roll the finished road every day for at least one week after the completion of the work.

Road Intersections

All intersections of roads are to be graded and macadamized in accordance with the plan, and in addition thereto broken stone of the 3-inch size must be spread beyond the macadam to a depth of 6 inches for a distance of 100 feet on the intersecting roads, and also at the ends of the macadam on the road being improved for at least 100 feet; berms shall be built to hold this stone in place.

The contractor will be required to grade and put in a condition satisfactory to the state highway commissioner all existing approaches of roads of lanes leading off the road.

MARYLAND

Macadam construction is to be used wherever directed by the engineer or provided for in the plans. The width and thickness required at different points is to be that designed by the engineer.

Classes A, B, and C

There ——— to be ——— class of macadam construction to be known as Class A, B, and C, respectively. ——— class shall consist of three courses of broken stone. The thickness after rolling of the various courses in —— class is to be as follows:

	First Course.	Second Course.	Third Course.
Class A	4 inches	2 inches	(To be as hereinafter described.)
Class B	5 inches	3 inches	
Class C	6 inches	4 inches	

Each course of broken stone is to be applied as herein specified.

Roadbed

MATERIAL

The roadbed for macadam construction is to consist of the natural earth roadbed, prapared and rolled until firm and hard in the following manner:

If sandy or other soil be encountered which will not compact readily under the roller, a small amount of clay, or other means satisfactory to the engineer, shall be used until a firm, hard surface is obtained after rolling.

CUTS AND FILLS

In cuts and fills, unless otherwise specially directed, the roadbed is to be graded to a width of ——— feet, and is to be free from all spongy and vegetable matter, roots, and stumps. The portion of the roadbed prepared for the broken-stone surface is to be ——— feet wide and brought to the grades and cross-sections as shown on the plans and rolled with a steam roller until firm and hard. All depressions that may appear during the rolling are to be filled with earth and rerolled until an even surface with a proper grade and cross-section is obtained.

OLD EARTH ROADBED

Where no change from the present grade of those portions of the road not already surfaced with stone is shown on the profile, the roadbed is to be shaped to the proper cross-section and slight elevations with contiguous depressions removed so as to form an even and smooth surface. The roadbed is to be rolled to a firm, smooth surface before the application of the broken stone.

TRENCH FOR THE BROKEN STONE

The portion of the roadbed prepared for the broken stone is to be below the sides by an amount equal to the thickness of the first course of stone so as to prevent the broken stone spreading at the sides.

SHAPE

The shape for the roadbed is to be as shown on the accompanying plans, and is to have a cross slope of ——— inch to 1 foot.

FIRST COURSE

MATERIAL

The first course of the macadam construction is to consist of sound stone broken to sizes varying from 3 inches to 2 inches, no piece to have a dimension greater than 3 inches. This is to be known as "No. 1" size.

No material is to be used which, in the opinion of the engineer, is unfit for the work. If any such material is put upon the road it shall be removed immediately upon notice from the engineer and replaced by proper material at the contractor's expense.

SPREADING

No broken stone is to be spread before the roadbed has been made as specified.

The broken stone is to be spread upon the roadbed, prepared as herein described, with shovels from piles alongside the road or from a dumping board, or it may be spread directly from wagons especially constructed for this purpose and approved by the engineer; but in no case shall the broken stone be dumped directly upon the roadbed.

ROLLING

After the broken stone for the first course has been spread to an uniform thickness, and has a proper cross-section, it is to be rolled with a steam roller, weighing not less than 10 tons, until it is compacted to form

a firm, smooth surface. Should any difficulty be experienced while rolling in having the stone readily compact, water shall be sprinkled or sand or other material be spread, as the engineer may direct. The rolling must begin at the sides and work toward the center, thoroughly covering this space with the rear wheel of the roller.

UNEVENNESS OR DEPRESSIONS

Should any unevenness or depressions appear, during or after the rolling of the first course, they are to be remedied immediately with broken stone and rerolled until a firm, even surface is obtained.

THICKNESS

The thickness of the first course of broken stone, after thorough rolling, is to be that of the class of macadam construction specified for any particular place as described under class A, B, and C.

If, for any reason, a greater thickness than specified is made by the contractor no extra allowance for such additional thickness will be made.

SHOULDERS

After the first course has been made as herein described earth shoulders are to be constructed along each side of the road for a width of at least —— feet as shown on the accompanying plans.

Against these shoulders is to be spread the broken stone for the second course as herein described. The shoulders are to contain a sufficient quantity of earth so that a smooth and continuous slope will be obtained after the shoulders and second course are rolled. The shoulders with the ——— feet of stone will make a total width of ——— feet to be shaped with a cross slope of ——— inch to 1 foot.

Material for the shoulders must be free from roots, stumps, or other vegetable matter and thoroughly compacted by the roller. Material with a proportion of sand such as prevents it when dry compacting readily under the roller, is not to be used.

No material which is considered unfit for the work by the engineer is to be used, and where any such is put on the work it shall be immediately removed, upon notice by the engineer, at the contractor's expense.

SECOND COURSE

The second course of the macadam construction is to be the same width as the first course.

MATERIAL

The second course is to consist of stone broken to sizes varying from 1 inch to 2 inches; no piece to have a greater dimension than 2 inches. This will be known as "No. 2" size.

Unless otherwise specified the stone for this course shall be trap rock with a "coefficient of wear," as determined by tests made at the laboratory of the highway division of the Maryland geological survey, of not less than 15, or limestone with a "coefficient of wear" of not less than 10.

SPREADING

The broken stone for the second course is not to be spread before the first course has been completed and shoulders made as herein specified.

The broken stone is to be spread upon the first course, prepared as herein described, with shovels from piles alongside the road or from a dumping board, or it may be spread directly from wagons especially constructed for this purpose and approved by the engineer; but in no case shall the broken stone be dumped directly upon the first course.

ROLLING

After the broken stone for the second course has been spread to a uniform thickness, and has a proper cross-section, it is to be rolled with a steam roller, weighing not less than ten tons, until it is compacted to form a firm, smooth surface. Should any difficulty be experienced while rolling in having the stone readily compact, water shall be sprinkled, or sand or other material be spread, as the engineer may direct.

The rolling is to begin at the sides, the shoulders first being rolled firm so as to prevent spreading of the broken stone in the second course. When completed the surface of the shoulders and of the second course of broken stone should be smooth and continuous with a cross slope of ——— inch to 1 foot.

UNEVENNESS AND DEPRESSIONS

If any unevenness or depressions appear during or after the rolling of the second course, either on the surface of the shoulder or the broken stone, suitable material shall be added to remove all such unevenness or depressions, earth being used on the shoulders and No. 2 stone for the broken-stone surface.

THICKNESS

The thickness of the second course of broken stone, after thorough rolling, is to be that of the class of macadam construction, specified for any particular place, as described under classes A, B, and C.

If, for any reason, a greater thickness than specified is made by the contractor, no extra allowance for such additional thickness will be made.

Third Course

MATERIAL

The third course of the macadam construction is to consist of trap rock screenings varying in size from dust to 1-inch pieces. Other material than trap rock screenings may be used if approved by the engineer. Limestone screenings shall be used with a limestone second course.

SPREADING

After the second course of No. 2 stone has been rolled and completed as above described the screenings are to be spread, but in no case are screenings to be used until the second course has been thoroughly rolled and compacted. The screenings are to be spread dry with shovels from piles alongside the road, or from dumping boards, but in no case are the screenings to be dumped directly on the second course. The quantity of screenings used is to be such as will just cover the second course.

WATERING AND ROLLING

After the screenings are spread they are to be sprinkled with water from a properly constructed sprinkling cart, and then rolled with a steam roller weighing not less than ten tons. The amount of water necessary is to be determined by the engineer. The rolling is to begin at the sides and to continue until the surface is hard and smooth and shows no perceptible tracks from vehicles passing over it.

If, after rolling the screenings, the No. 2 stone appears at the surface, additional screenings shall be used in such places.

The rolling and watering shall continue until the water flushes to the surface. The rolling is to extend over the whole width of the road, including the shoulders.

UNEVENNESS AND DEPRESSIONS

If any unevenness or depressions appear in the road surface after rolling the screenings, No. 2 broken stone and screenings shall be used until they are removed and the finished surface conforms to the proper cross-section, as shown on the accompanying plans, and presents a smooth, even appearance.

PART III

CITY STREETS AND PAVEMENTS

CHAPTER XIII

THE DESIGN OF CITY STREETS *

MOST cities grow up gradually, without any comprehensive or prearranged street plan, and without adequate regulations governing suburban development. Streets are laid out in the interests of individuals, and cities are developed under the stimulus of real estate speculation, regardless of the interests of the public. It is usually after the city has grown to a considerable size, that the remedy is applied for this ungoverned development, and in some instances cities have spent vast sums in correcting what might have been prevented by an adequate plan of street design.

Objects in planning city streets.

In planning the streets of a city, the objects to be kept in mind are:

1. The subdivision of the area to give the maximum efficiency for business and residence purposes.
2. Sufficient accommodation for the pedestrian and vehicular traffic on the streets.
3. Good drainage and easy communication between the different parts of the city.

In the subdivision of the area, it is desirable to make the size of lots such that few of them will be further subdivided, as clearness of identity is always maintained by referring

* Prof. I. O. Baker, in his "Roads and Pavements," deals more thoroughly than any other writer with this feature of municipal work.

to the original number in transferring or assessing the property. Experience has shown that a frontage of 25 feet and a depth of from 100 to 150 feet is the best. This size is suitable for business purposes, and for residence streets two or more lots give proper grounds.

Size of blocks.

With a rectangular system of streets, the blocks are preferably long and narrow, since the distance required between streets in one direction is only that necessary to give the proper depth of lots, while in the other direction the streets need be only close enough to provide convenient channels for the traffic. For convenience, especially in business districts, it is best to have an alley, from 16 to 20 feet wide, run lengthwise through the block.

Sizes of blocks vary in any particular city and still more between different cities. The following are the sizes of some typical blocks:

Boston	200×400 ft. and 100×550 ft.
New York	200×900 " and 200×400 "
Philadelphia	400×500 " and 500×800 "
Washington	400×600 " and 300×800 "
Montreal	250×750 "
Chicago	300×350 " and 300×500 "

Fig. 165 is given by Baker * to illustrate the advantages to be derived from a careful study of the best size of blocks and of the most advantageous arrangement of streets. The left-hand side of the diagram shows the typical arrangement of streets and blocks in the residence district of New York City, the shaded portions representing the usual buildings. Here the three center blocks comprise an area of 720×800 feet, and contain 480,000 sq.ft. of building area and 96,000 sq.ft. of streets. The right-hand side shows a much superior arrangement in which in a corresponding area there are 481,000 sq.ft. of building area and 94,200 sq.ft. of streets.

* "Roads and Pavements," p. 309.

The two plans, therefore, give substantially the same area for buildings and for streets. In the first case the length of streets is 1,600 feet, in the second 1,520 feet; therefore the two plans have practically equal light and air, but the second arrangement is the better in the following particulars:

1. Number of corner sites.
2. Accessibility of rear entrances for delivery of provisions,

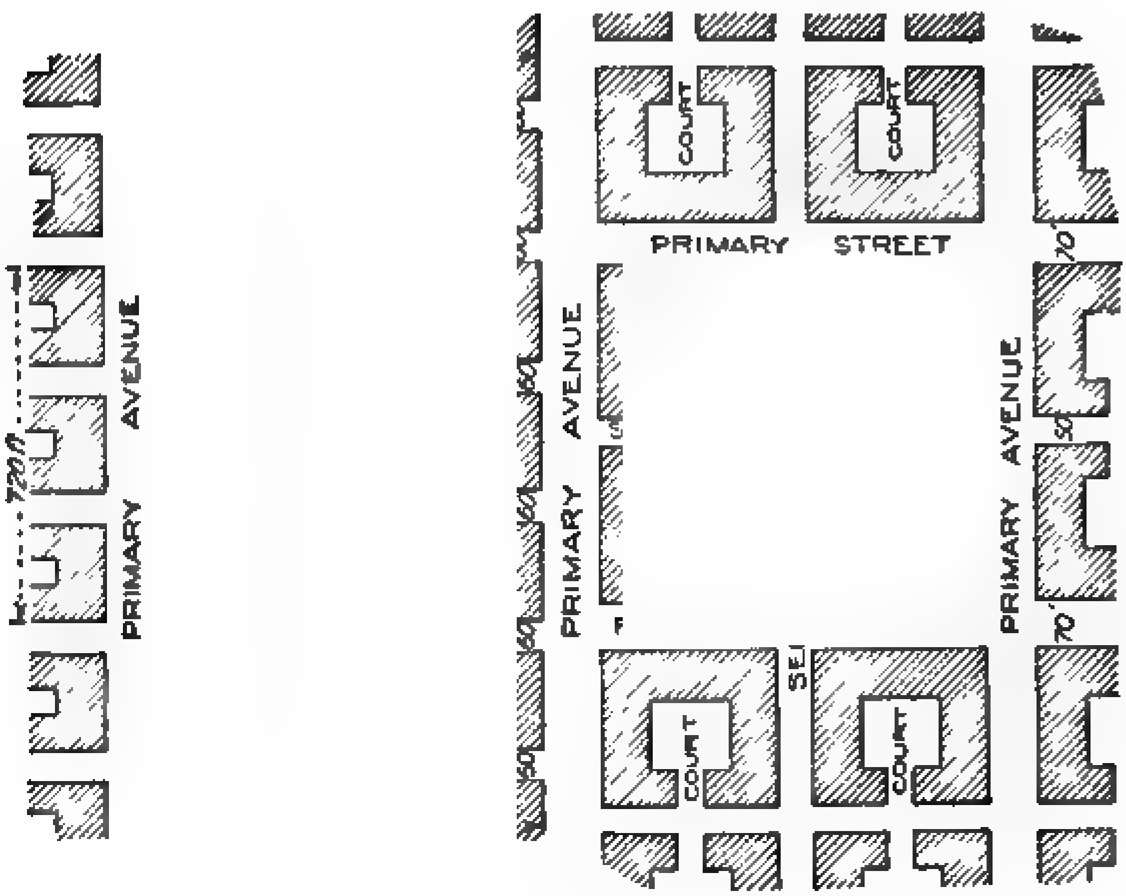

FIG. 165.—Improved Arrangement of Streets and Blocks

coal, etc., and the removal of garbage, ashes, etc., and in case of fire.
3. Removal from the street of dangerous and cramped cellar entrances.
4. Removal from the main and primary streets of the loading and unloading of trucks.
5. Increased transportation facilities in a direction perpendicular to the length of the original blocks.

In planning a system of streets, drainage and easy communication between the different sections of the city should

be carefully considered. Surface drainage, sewerage and traffic must follow the general slope of the land, and therefore if there is much irregularity of contour in the site, a location of the streets with reference to the contours will afford at once the best drainage and the easiest communication between different parts of the city. If the site is nearly level, the relationship between the slope of the land and the direction of the streets is comparatively unimportant; but the arrangement of the street plan to afford the greatest facilities for communication between the different parts of the city is still an important matter. The conclusion is, therefore, that on a site of irregular contour, the streets should be located with reference chiefly to the topography, and on a level site primarily to secure the most direct and easiest intercommunication.

Location of streets.

Surface drainage, sewerage and traffic should follow the slope of the country, and any attempt to deviate from this becomes a serious question in the building of a city upon any but nearly level ground. The streets are of necessity the drainage lines of the city and should be placed in the natural valleys, and the failure so to locate the streets in many cities where the land is very irregular in contour has led to great expense in the construction of the streets and of a system of storm-water sewers. The upper half of Fig. 166 shows an actual case of a system of rectangular streets located without any reference to the topography of the site; and the lower half of the same diagram shows a proposed arrangement* that would save much expense in grading the streets and at the same time give a quick entrance into the center of the city, and also long easy grades from the heart of the city to the higher outlying districts.

There are three distinct general plans for location of city streets with reference to directness and ease of communication. One consists of a system of parallel streets crossing a similar system at right angles, often called the "checkerboard," but more properly the "rectangular" system, since

* By W. D. Elder, in Proc. Mich. Eng. Soc., 1898, p. 52.

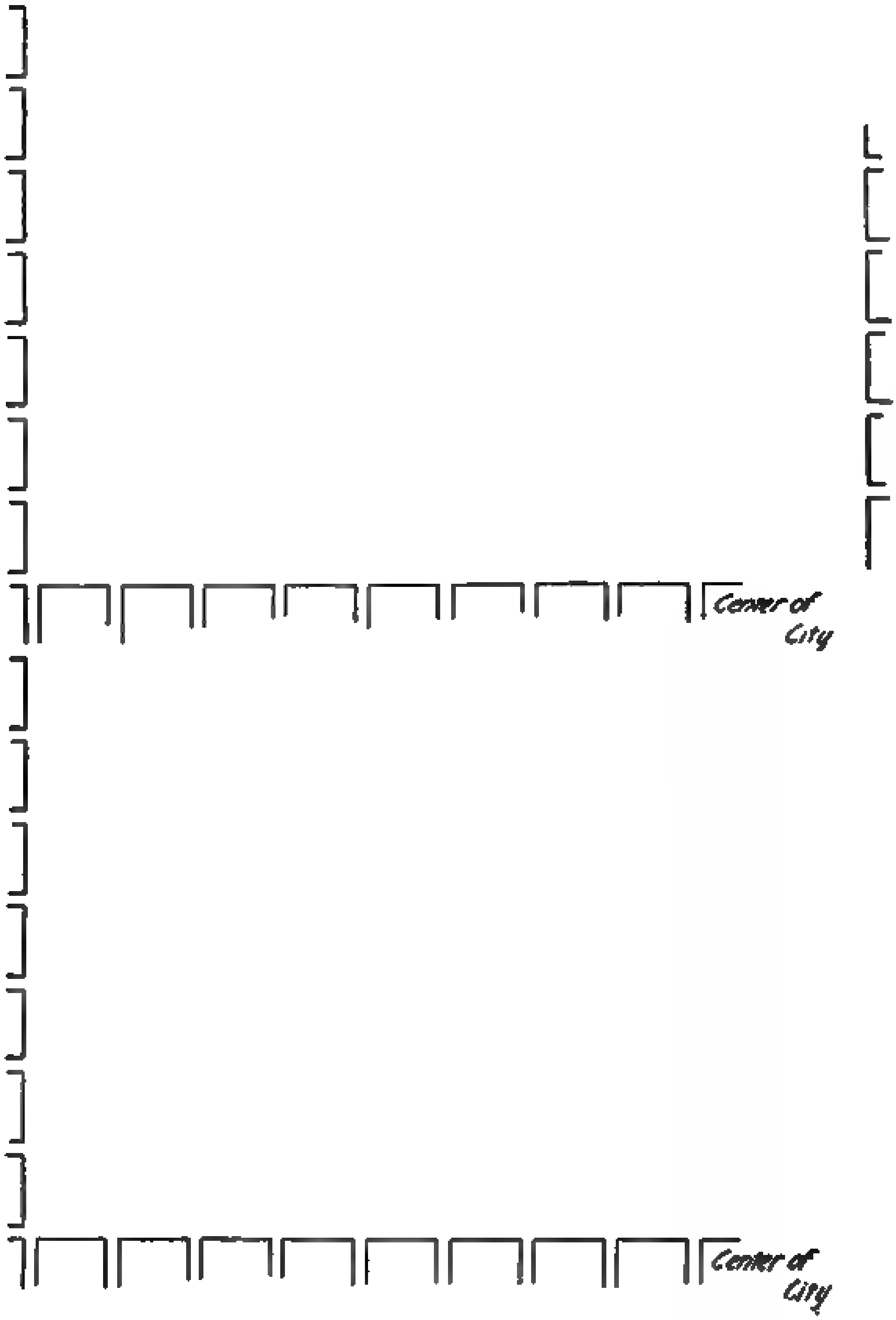

Fig. 166.—Location of Streets with Reference to Contours.

the blocks are not necessarily square. This arrangement, which is the most common, gives a maximum area for blocks, and also furnishes blocks of the best form for subdivision into lots. The second arrangement of streets consists of a rectangular system with occasional diagonal streets along the lines of maximum travel. This system, sometimes called the "diagonal" system, was employed by L'Enfant in planning the city of Washington, and to a limited degree, was adopted in laying out the city of Indianapolis, which has four broad diagonal avenues converging to a circular park in the center.

General plans for location of streets.

The chief advantage of the diagonal streets is the economy due to the saving of distance by traversing the hypothenuse instead of the two sides of a right triangle. The two American cities mentioned are the only places of importance in which the system was adopted in advance of the building, but in Rome, London, Paris, and in numerous smaller places in Europe, whole districts have been razed to make way for new streets to serve as arteries for increased traffic. A second, and by no means an unimportant advantage of the diagonal system, is the open squares and spaces so grateful to the eye and in compactly built cities of no little sanitary value.

Although the diagonal avenue occupies ground that might otherwise be used for building purposes, there is a compensating advantage in the greater length of street front obtained.* In many cases the total cost of cutting diagonal streets through built-up districts has been paid by the increased value of the property on and near the street thus opened up.

The third arrangement of city streets is the "ring" or "concentric" plan, which is very popular in Europe. The most noted example is Vienna with its Ring-strasse (Ring street) within and its Gurtel-strasse (Girdle street) without. The former is 187 feet wide and encircles the public buildings and the leading houses of business and amusement. The enclosed network of streets intersect the Ring-strasse at

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* For a discussion of this phase of the subject, see an article by L. M. Haupt, in *Journ. Franklin Inst.*, Vol. 103, p. 252.

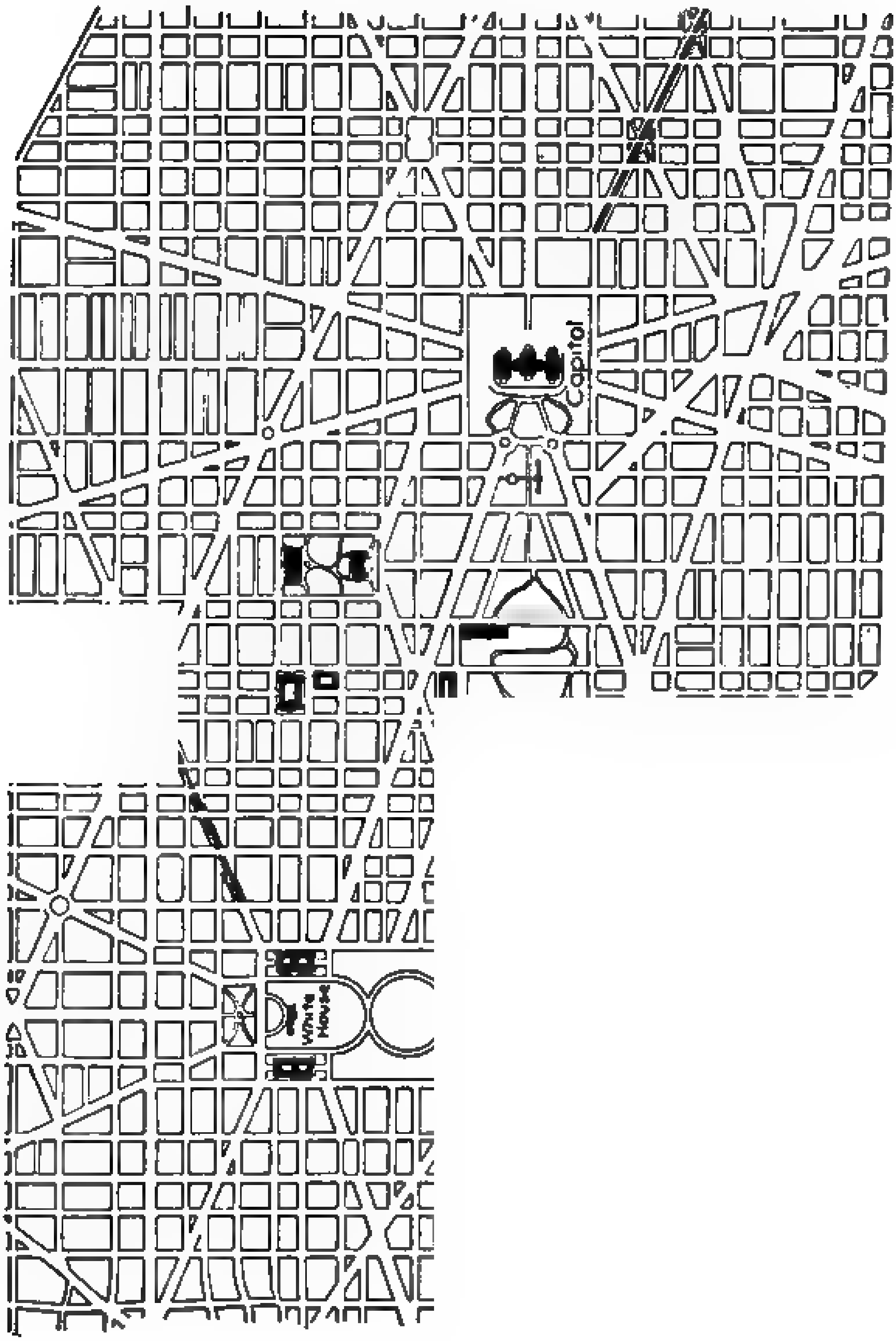


FIG. 167.—Street Plan of Washington, D. C.

forty points, and outward from it extend fifteen main radial avenues.

Width of streets.

The width of city streets is important on account of its influence upon the ease with which traffic may be conducted and also because of its effect upon the health and comfort of the people by determining the amount of light and air which may penetrate into thickly built-up districts. The streets of nearly all large cities are too narrow, being crowded and dark. A more liberal policy in planning streets would probably be of pecuniary advantage, as wide streets usually give a high financial value to adjoining property. A lot 100 feet deep on a street 80 feet wide is usually more valuable than a lot 110 feet deep on a street 60 feet wide; that is to say, within reasonable limits land is usually more valuable in the street than on the rear of the lot. Wide streets are especially needed where they are bordered by high buildings or are to carry street railway lines.

In order properly to accommodate the traffic in business districts of cities of considerable size, a street should have a width of 100 to 140 feet, the whole of it being used for roadway and side-walks; while residence streets in a city of considerable size, where the houses are set out to the property line and stand close together, should have a width of 60 to 80 feet. Although it is advantageous to have a wide street, it is not necessary, nor even desirable, that the whole width be paved; the central portion may be paved, a strip on either side being reserved for grass plats. The width of the pavement should be adjusted to the amount of traffic, which varies greatly accordingly as the street is a business street, a thoroughfare, or an unfrequented residence street.

The width of the streets in different cities varies greatly. In the older places in New England and the Central States, many of the streets are only 30 to 40 feet wide; but in the West a street is seldom less than 60 to 66 feet wide. In both regions the principal streets are often 80 to 100 feet wide, and in many of the larger cities the boulevards and great

avenues are 150 to 180 feet. The main avenues in Washington are 160 feet wide, in New York 135, and in Boston 180 feet.

At present the regulations governing the width and the arrangements of additions and subdivisions of Washington, a city which has the best street plan of any in America, are:

"No new street can be located less than 90 feet in width, and the leading avenues must be at least 120 feet wide. Intermediate streets 60 feet wide, called places, are allowed within blocks; but full-width streets must be located not more than 600 feet apart."

Area of streets.

The proportion of the area of the city devoted to streets varies greatly, particularly between the older and the newer cities. The following is the per cent of street area in a few extreme cases of American cities:*

Minimum Street Area.	Per Cent.	Maximum Street Area.	Per Cent.
1. Taunton, Mass.	3.20	Duluth, Minn.	86.7
2. Worcester, Mass.	5.43	Dallas, Tex.	78.3
3. Binghamton, N. Y.	7.55	Denver, Colo.	73.9
4. Philadelphia, Pa.	8.42	Indianapolis, Ind.	56.4
5. Boston, Mass	8.76	Washington, D. C.	43.5
6. Lowell, Mass.	8.92	Davenport, Ia.	42.1
7. Fall River, Mass.	9.17	Evansville, Ind.	40.8

The area devoted to streets and alleys in a few of the principal cities of the world is as follows:

Area of Streets and Alleys.	Per Cent.
1. Washington	54
2. Vienna	35
3. New York City	35
4. Philadelphia	29
5. Boston	26
6. Berlin	26
7. Paris	25

* Census Bulletin, No. 100, July 22, 1891, p. 16.

Table XV

Acres required per Mile for Different Widths of Roadway.

Width. Feet.	Acres per mile.	Width. Feet.	Acres per mile.	Width. Feet.	Acres per mile.	Width. Feet.	Acres per mile.	Width. Feet.	Acres per mile.
¼	.030	19	2.30	40	4.85	59	7.15	80	9.70
½	.061	20	2.42	41	4.97	60	7.27	81	9.82
1	.121	21	2.55	41¼	5.00	61	7.39	82	9.94
2	.242	22	2.67	42	5.09	62	7.52	82½	10.00
3	.364	23	2.79	43	5.21	63	7.64	83	10.06
4	.485	24	2.91	44	5.33	64	7.76	84	10.18
5	.606	24¾	3.00	45	5.45	65	7.88	85	10.30
6	.727	25	3.03	46	5.58	66	8.00	86	10.42
7	.848	26	3.15	47	5.70	67	8.12	87	10.54
8	.970	27	3.27	48	5.82	68	8.24	88	10.66
8¼	1.00	28	3.39	49	5.94	69	8.36	89	10.78
9	1.09	29	3.52	49½	6.00	70	8.48	90	10.90
10	1.21	30	3.64	50	6.06	71	8.61	90¾	11.00
11	1.33	31	3.76	51	6.18	72	8.73	91	11.03
12	1.46	32	3.88	52	6.30	73	8.85	92	11.15
13	1.58	33	4.00	53	6.42	74	8.97	93	11.27
14	1.70	34	4.12	54	6.55	74¼	9.00	94	11.39
15	1.82	35	4.24	55	6.67	75	9.09	95	11.51
16	1.94	36	4.36	56	6.79	76	9.21	96	11.63
16½	2.00	37	4.48	57	6.91	77	9.33	97	11.75
17	2.06	38	4.61	57¾	7.00	78	9.45	98	11.87
18	2.18	39	4.73	58	7.03	79	9.58	99	12.00
								100	12.12

Width of pavement.

It is wise to make the streets of residence districts of liberal width for sanitary and aesthetic reasons, and also because the future of the street cannot be certainly foreseen—the residence street may become a business street, or an unfrequented street a thoroughfare. However, it is not necessary that the whole width should be devoted to wheelways and sidewalks, particularly in small cities. A grass plat between the sidewalk and the pavement, in which shade trees are set, adds to the beauty of the street and to the comfort of the residents, by removing the houses farther from the noise and dust of the pavement. The grass plat, or parking, also affords an excellent place in which to place water or gas pipes, telephone and electric-light conduits, etc. In large cities where the street front is built up solid with houses of several stories, it may be necessary to dispense with the grass plat, and devote the entire street to sidewalks and roadway.

For some reason, it has long been the custom to pave streets from curb to curb. Possibly this practice grew out of the necessity of paving business streets from curb to curb, and as business streets are the first to be paved in every city, it was not unnatural that when later the residence streets were also paved, similar designs prevailed. The idea that all of the street must be paved is often shown in the sudden increase in the width of metalled roadway, where a macadam road enters a city. Thus, on several of the streets in Rochester, N. Y., the width of macadam is more than double the width of macadam on the road just beyond the city limits, and that this practice is widespread is shown by the reports of many city engineers.

Driving in middle of road destructive.

There is little justification for the expenditure of money involved in paving residence streets their full width; rarely is there a residence street where traffic is great enough to justify a paved trackway greater than 16 or 18 feet in width, and if the passing vehicles on any residence street are watched it is seen that they cling closely to the center. No argument will convince the public that it is poor pavement economy to always travel in the one narrow path, and in spite of signs, and warning notices, both horse and driver will continue to use the center of the road. The horse finds it easier travelling in the center where all four feet are on a level, and the driver finds it pleasanter riding where the seat is also level; so animal and human comfort take precedence over pavement economics. Some time ago the Massachusetts board of highway commissioners caused to be erected along the highways of that state signs requesting drivers of all kinds of vehicles not to drive in the middle of the road. This action was taken because driving in the center of the road was believed to be responsible for the heavy repair expenditure necessary. After the sign idea had been given a fair trial the commissioners reported that the cost of repairs was much less where the order was obeyed than where it was disregarded. Fig. 168 shows such a sign on a state highway near Sterling, Mass.

Since, then, the center of a street receives practically all the

travel, there seems little reason for paving areas seldom used except by occasional carriages and delivery wagons stopping in front of houses. This area might economically be left unpaved, as an earth road is usually only very bad during the wet season of the year, and then its badness varies directly with the amount of traffic that it must bear. It is not the occasional passing of a wheel over an earth road that cuts it into ruts, but the repeated passage of many wheels which churn the water and the earth together, until deep ruts are formed ready to receive the very next fall of rain and store it there.

In Venice, California, a sea-side town fifteen miles from Los Angeles, center-walks have superseded sidewalks.

Fig. 168.

Center-walks instead of sidewalks.

The innovation practically converts the many short streets leading from the ocean front into recreation grounds, where children may play in safety without fear of being dispersed or injured by passing vehicles. By mutual agreement between the property owners and the city officials, all vehicular traffic is excluded from certain streets, the tradesmen and others being relegated to the use of 20-foot alleys which abut upon the rear of all lots fronting upon the cross streets.

Park avenue, shown in the accompanying view, is one of over thirty streets which have been improved at the expense of the abutting property owners with the centerwalk system.

From houseline to houseline, the "street" is 40 feet in width, extending 350 feet at right angles with the ocean. The walk down the center varies, according to the choice of property owners, from 10 to 15 feet in width. It is laid strictly according

FIG. 160.—Center-walk in Place of Roadway and Sidewalks, Park Avenue, Venice, Cal.

to specifications, recommended by the city engineer, approved by the board of trustees and filed at the city hall.

The specifications call for 3½-inch concrete foundation, laid upon the sand composing the street. No joints are permitted, except where work is stopped from day to day, and at such points a reinforcement of chicken-wire must be laid, the full width of the walk, where the concrete work is renewed.

The specifications also call for a continuous strip of chicken-wire netting reinforcement, 3 feet wide, of not more than 3-inch mesh, on each side of the center line of the walk, midway between the middle and the outer edge.

On top of the concrete base is spread a ½-inch finishing coat, composed of equal parts of cement and sand. The surface is neatly marked off in squares, while moist, and coloring matter, usually red or slate gray, is added to give the finished walk any hue desired.

One detail of the specifications, which tends to guarantee good workmanship, is the direction that the contractor must stamp his name in letters not less than ¾-inch in height and ¼-inch deep in the pavement at least once in every 60 linear feet of the work.

In the pavement shown herewith, the contract figures for the walk were 12 cents per square foot for the pavement and 16 cents per linear foot for the curbing. The latter, in most instances, is made a part of the walk, extending down into the sand on either side for 6 or 8 inches, thus acting as an anchor for the whole.

With the exception of a few thoroughfares which connect with county roads in the interior, all of the streets bordering upon the waterfront in Venice have been paved with a center-walk, built either of concrete or wood.

Freedom from the noise of passing vehicles, with the consequent clouds of dust; the safety and comfort of residents and the exceptional opportunity for ornamental effects offered by the exclusion of traffic and the conversion of the roadways into footways are distinctions peculiar to this system of street design.

It is universally admitted that pavements are desirable;

but often, owing to the unwillingness of at least some of the people to pay for them, or to the idea of some that they must have a pavement from curb to curb or none at all, it is difficult to secure them. Within reasonable limits of cost wide pavements are desirable, but length is more valuable than width. Excessive width delays or prevents the getting of any pavement at all; hence one help toward securing a pavement is to make the pavement only wide enough to accommodate the traffic. A narrow pavement not only costs less to construct, but also costs less to clean, while the cost of maintenance depends chiefly (or, with a pavement not subject to natural decay, wholly) upon the amount of traffic and hence is practically independent of the width.

CHAPTER XIV

STONE BLOCK PAVEMENTS

STONE in a variety of forms has been used for paving purposes from the earliest times. In the form of blocks its earliest systematic use was by the Romans, whose roads were practically works of solid masonry construction, built of irregularly shaped stones, but finished to a smooth and true surface. These roads were wasteful of material but were remarkable for their strength, durability and excessive cost, which, however, was principally in the lives of captives, who were forced to build these highways for the armies of their conquerors.

Roman roads.

Under Julius Cæsar, Rome was in complete communication with all the principal cities of its great empire by such paved roads, which were distinguished by the names *Via*, *Actus*, *Iter*, *Semita*, *Trames*, *Diverticulum*, *Divertium*, *Callais*, etc.

The *Via* corresponded with our common roads, and had a width of 8 Roman feet.

The *Via Militari* and other important roads in the neighborhood of Rome had a double width, 16 Roman feet (15 ft. 6 ins. English), and *margines*, or sidewalks, 8 feet wide. The middle, convex portion was paved with blocks and divided from the sidewalks by a curb of low wall, 2 feet wide and 18 inches high. The middle was for the infantry; the *margines* for carriages and equestrians.

The *Actus* was 4 feet wide, for single carriages.

The *Iter*, for horsemen, pack animals, and pedestrians, the width of which was 3 feet. *Semita* was only half the breadth of the *Iter*, and was called *Diverticulum*, or *Divertium* when it branched across fields. The *Semita* on steep grades was frequently in the form of steps.

The *Callais* was a mountain path, used principally by shepherds.

The *Via Appia*, Appian Way, was not only the earliest military road, but the best constructed. It extended from Rome to Brindusium (now Brindisi), a distance of 360 miles, and was constructed principally by Julius Cæsar. The mode of construction, which was, in general, the same as used in all important military roads, was as follows:

The course being decided upon, in as nearly straight lines as possible, it was marked by two parallel trenches excavated at varying distances apart according to the importance of the highway. This also showed the nature of the subsoil, from which the level of the foundations was determined; all unstable materials were removed to a depth of about 3 feet, the

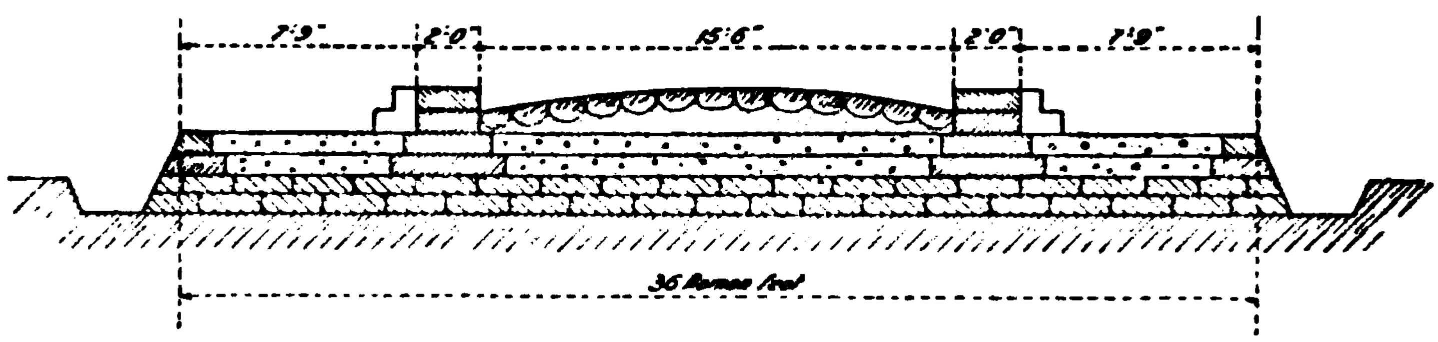


FIG. 170.—Cross-section of Roman Road (Appian Way).

bottom was consolidated by ramming until a solid foundation was obtained. In this undrained trench the road materials were placed in more or less regular layers.

The *statumen*, or base, consisted of two courses of large flat stones laid in lime mortar, and was usually about 15 inches thick. Upon this was laid the *rudus*, or rubble, consisting of a 9-inch course of small fragments of stone embedded in sufficient lime mortar to fill their voids.

Upon this, the *nucleus* was formed of fragments of gravel, stone, pottery and brick mixed with lime mortar to form a concrete, which was laid while hot and consolidated by ramming, and was made about 6 inches thick. The *summa crusta* (top crust) or *pavimentum* (hard surface) was formed of closely jointed, irregular stones, which formed a mosaic about 6 inches thick, the top of which was practically on a level with the adjoining natural surface of the ground.

In and near the cities the *pavimentum* was formed of larger irregular blocks of basalt, or porphyry or lava, 2 to 2½ feet in length and width and 12 inches to 15 inches in thickness, which were dressed and fitted together with extreme accuracy and were bedded in cement. On these roads were carried huge columns, obelisks, and other blocks weighing hundreds of tons, without any injury to the surface.

The earliest pavements were constructed in almost every case of rough stone, which were the most available and at the same time, most durable. As the need for better pavements increased with the growth of cities, the rough cobble-stone was gradually superseded by stones formed into the shape of blocks which gave a comparatively smooth surface. This was the beginning of the modern stone-block pavement, and in

FIG. 171.—Cross-section of Cobblestone Pavement.

European countries the pavements have improved until they had developed into something of a standard made of blocks about 6 by 8 inches square, and of depths varying according to the traffic.

Cobblestone pavement.

In this country, however, the original pavements were all of cobble. Most of the cities were poor and the cobblestones being available and cheap, naturally came into quite common use. They gave good service, but were rough, uneven and very noisy.

Little, if any, cobblestone pavement is now being laid. In a few localities where the property owners pay the first cost and are then relieved of further cost of maintenance or relaying, its cheapness has been a sufficient inducement to cause it to be used, but is never gives satisfaction and is really only a makeshift for a pavement. In the days when pave-

ments of this class were extensively laid and the demand for the stones became so great that suitable ones were obtained only at considerable expense and with some difficulty, almost anything in shape and size was permitted to be used, and the specifications were most shamefully abused. The result was that cobblestone pavements were even worse than they would have been had they been properly laid. The specifications generally provided that the stones should be the best selected water or bank cobblestones, of a durable and uniform quality, with round heads and well-shaped large ends. They should be not less than 4 inches nor more than 8 inches in diameter across the head, nor less than 5 inches nor more than 10 inches in depth; no triangular, split or otherwise ill-shaped stones should be used, nor any which are soft or rotten.

Since the introduction of asphalt and brick pavements and since the decrease in the cost of stone-block pavement by the introduction of improved methods of quarrying, and in the cost of broken-stone roads by the invention of the rock-crusher and the road-roller, there is little excuse for the construction of the cobblestone pavement. In some cities it has been prohibited by law, but the old pavements still exist in such quantities that it will require some years of active work in repaving before it is entirely extinct. Practically the only paving for which cobblestones are now used is in yards and alleys, and for gutters and crossings of unpaved streets.

Following the cobblestone and in response to the demand for an improvement on them, came what has always been known in this country as the "Belgian block." In shape it was a truncated pyramid, with base about 5 or 6 inches square, and a depth of from 7 to 8 inches, the bottom of the block being of dimensions of not more than 1 inch different from the top. This was an improvement on the cobblestone and when well shaped and of proper material made a very good pavement. It was introduced into New York and vicinity about 1850, and it soon became quite popular.

This form of pavement was the result of a development in Europe from the early pavements, made of large rectangular blocks. These had several square feet of top surface and

were laid lengthwise of the street, but as traffic increased, it was found that the long joints, being parallel to the direction of travel, rapidly wore into ruts and the pavement became rough and uneven. To obviate this, the blocks were made square and were laid with their sides at an angle of 45 degrees with the line of the street. These large blocks soon proved unsuitable for heavy traffic, as it was difficult to bed them so that they would keep their place, and as their large surface did not afford a good

Belgian block pavement.

FIG. 172.—Cobblestone Hammer.

FIG. 173.—Stone Paver's Hammer.

FIG. 174.—Cobblestone Rammer.

FIG. 175.—Stone block Rammer.

foothold for horses. This led to the use of smaller square blocks with their edges parallel and perpendicular to the line of the street. For many years this form of pavement has been common in the cities of Europe, the blocks usually having a top surface of 5 to 7 inches square and a depth of 6 inches. The first use of this form of pavement was in Brussels, Belgium.

In New York and vicinity it has been laid almost entirely of trap-rock from the Palisades of New Jersey. This rock is hard and durable, but after some wear becomes smooth and slippery. On account of its being, at first, made of this trap-rock, all trap-rock pavements have been called "Belgian

pavements," but when made of the oblong blocks similar to those of the ordinary granite they have been called in distinction, "specification Belgian." This is a complete misnomer, as the name refers distinctly to the shape and not to the character of the material, as some Belgian pavements have been made of granite.

The objections to the Belgian block are:

1. On account of the size and form of the blocks it is difficult to keep them in place.

2. The blocks are of such size and form as to give horses a poor foothold.

3. The blocks being square there is always a considerable

FIG. 176.—Cross-section of Stone-block Pavement.

length of joints parallel to the line of travel, which causes ruts to form in the pavement.

As the blocks became more common, deviations were allowed from the specifications, with the result that the blocks were too small on the base to allow a solid bearing. Also under traffic they soon got out of position, and in consequence the pavement became rough. An improvement in the Belgian block was to make the block an exact cube. Many European cities at the present time lay blocks of that shape.

Granite block pavement.

Just as the Belgian block supplanted the cobblestone, it has itself been gradually displaced by the introduction of rectangular blocks of granite. Blocks of comparatively large dimensions were at first employed, being merely placed in rows on the subsoil, perfunctorily rammed, the joints filled with sand, and the street thrown open to traffic. The unequal settlement of the blocks, the insufficiency of the foothold, and the diffi-

culty of cleansing them led to the gradual development of the later type of stone-block pavements, consisting of narrow rectangular blocks of granite, properly proportioned, laid on an unyielding and impervious foundation, with the joints between the blocks filled with an impermeable cement. This type is practically a return to the system of the Romans, but with blocks of lesser dimensions than they used.

Experience has proved that this type of pavement is the most enduring and economical for roadways subjected to heavy and constant traffic. Its advantages are:

Advantages and defects.

1. Adaptability to all grades.
2. Suitable for all classes of traffic.
3. Exceedingly durable.
4. Fair foothold.
5. Easily kept in repair.
6. Yields little dust or mud.
7. Moderately easy to clean.

Its defects are:

1. Greasy and slippery surface when damp.
2. Noisy. The constant noise of the traffic over it is an intolerable nuisance and is claimed by physicians to be injurious to the nerves and health of persons who live or do business near it.
3. Wear on horses resulting from the continual jarring produced in their legs and hoofs.
4. Discomfort to persons riding over it.
5. If smooth-wearing rocks are used, the surface quickly becomes slippery and unsafe.

Quality of the stone.

The harder and more durable rocks like basalt and true granite are unsuitable, as they have the fault of wearing smooth when subjected to heavy traffic, and under certain conditions of the weather they become greasy and slippery. The less durable rocks, such as syenite, and the harder sandstones, are the most suitable; they do not polish and afford a good foothold for the horses.

The size of the blocks has varied considerably, and a great variety of forms and dimensions are to be found in all cities. For stability a certain proportion must exist between the

depth, the length, and the breadth. The depth must be such that when the wheel of a loaded vehicle passes over one edge of its upper surface it will not tip up, otherwise the maintenance of a uniform surface is impossible. To fulfill this requirement it is not necessary to make the block more than seven inches deep.

Size and shape of the blocks.

The maximum width of the blocks is controlled by the size of horses' hoofs. To afford good foothold to horses drawing heavy loads, it is necessary that the width of each block measured along the street shall be the least possible consistent with stability. It is desirable, therefore, that the width of a block should not exceed three inches, or that four taken at random and placed side by side will not measure more than fourteen inches.

The length measured across the street must be sufficient to break joints properly, for two or more joints in a line lead to the formation of grooves. For this purpose the length of the block should be not less than nine inches nor more than twelve inches.

The blocks should be well squared and must not taper in any direction, and both sides and ends should be free from irregular projections.

Manner of laying the blocks.

The blocks should be laid in parallel courses, with their longest side at right angles to the axis of the street, and the longitudinal joints broken by a lap of at least two inches, to prevent the formation of longitudinal ruts, which would happen if the blocks were laid lengthwise.

At junctions or intersections of streets the blocks should be laid diagonally from the centre to prevent the traffic crossing the intersection from following the longitudinal joints and thus forming depressions and ruts, and affording better foothold for horses turning the corners.

Foundation.

The foundation of the blocks must be solid and unyielding, and for this, hydraulic cement concrete is extensively used. The thickness must be regulated according to the traffic, but should not be less than four inches and need not be more than nine inches. A thick-

ness of six inches will sustain a traffic of 600 tons per foot of width.

Between the surface of the concrete and the base of the blocks there is placed a cushion-coat formed of fine, clean and dry sand, which readily adjusts itself to the irregularities of the base of the blocks and transfer the pressure of the traffic uniformly to the concrete below.

Laying the blocks.

The blocks are laid stone to stone, so that the joint may be of the least possible width; wide joints cause increased wear and noise and do not increase the foothold. The courses are commenced on each side and worked toward the middle, and the last stone should fit tightly.

After the blocks have been set they are well rammed down, and the stones which sink below the general level are taken up and replaced with a deeper stone or brought to level by increasing the sand-bedding.

Joint-filling.

All stone-block pavements depend for their water-proof qualities upon the character of the joint-filling. Joints filled with sand and gravel are of course, pervious, while a grout of lime or cement mortar does not make a permanently water-tight joint, as it becomes disintegrated under the vibration of the traffic. An impervious joint can only be made by employing a filling made from bituminous or asphaltic material; this renders the pavement more impervious to moisture, makes it less noisy, and adds considerably to its strength.

The bituminous materials employed are: 1. The tar produced in the manufacture of gas, which, when redistilled, is called *distillate*, and is numbered according to its density; this material, under the name of *paving-pitch*, is extensively used both alone and in combination with other bituminous substances; 2. Combinations of gas- or coal-tar with refined asphaltum; 3. Mixtures of refined asphaltum, creosote, and coal-tar.

Stone blocks may be employed on all practicable grades, but on grades exceeding ten per cent. cobblestones afford a better foothold than blocks. If stone blocks are used, they

Fig. 177.—Filling in Stone-block Pavement with Asphalt Bitose Filler.

Pavements on steep grades.

must be laid, when the grade exceeds five per cent., with a serrated surface, made by slightly tilting the blocks on their bed so as to form a series of ledges or steps against which the horses' feet being planted, a secure foothold is obtained. Another method consists in placing between the rows of stones a course of slate, or strips of creosoted wood, rather less than one inch in thickness and about an inch less in depth than the blocks; or the blocks may be spaced about one inch apart, and the joints filled with a grout composed of gravel and cement.

The average life or durability of granite blocks under heavy

FIG. 178.—Arrangement of Stone Blocks on Steep Incline

Durability of granite blocks.

traffic may be taken at fifteen years; but since the nature of the traffic, the state of cleanliness and other conditions must be taken into account when inquiring into the durability, it follows that in no two streets is the endurance and the cost the same, and the difference between the highest and the lowest period of endurance and amount of cost is very considerable. The practice followed in European cities is to remove the worn blocks, re-dress them and re-lay them in other and secondary thoroughfares. Thus the duration of life of the blocks may be doubled, or more than doubled. In fact, with the exception of the portion worn off by the friction of the traffic, not a fragment of granite paving may be said to be lost. After passing its first years in a leading thoroughfare it goes into a secondary thoroughfare until completely worn down and rounded, and

not even a fragment that is knocked off the component stones when undergoing the operation of being dressed into shape is lost, as it is made available either for macadamizing or for concrete to form the foundation of other pavements. Granite can only be said to be worn out when it has been broken up for macadamizing and then crushed into powder by the vehicles.

Stones from different quarries and even from the same quarry will show considerable variation in the amount worn away in a given time under exactly similar conditions. Therefore no statement of wear can be given which will be applicable to all varieties of stone.

CHAPTER XV

BRICK PAVEMENTS

Brick pavements consist of bricks laid on edge on a suitable foundation of concrete, gravel, sand, or wood. Although brick is one of the oldest materials used for paving, its first use for this purpose in the United States was in Charleston, W. Va., about 1870. Since then the use of brick as a paving material has steadily increased, and in localities with moderate traffic it has given satisfaction.

Advantages and defects.

The advantages of brick pavements are:

1. Ease of traction.
2. Good foothold for horses.
3. Not disagreeably noisy.
4. Yields but little dust and mud.
5. Adapted to all grades.
6. Easily repaired.
7. Easily cleaned.
8. But slightly absorbent.
9. Pleasing to the eye.
10. Expeditiously laid.
11. Durable under moderate traffic.

In many localities brick is superior to wood or broken stone, and in cities and towns will often be found superior to stone blocks.

The principal defects of brick pavements arise from (1) lack of uniformity in the quality of the bricks, and (2) the liability of incorporating in the pavement bricks of too soft or porous structure, which crumble under the action of traffic or frost.

Quality of brick

The employment of unsuitable brick may be fostered by a desire to help a local industry without due regard to the quality of the local clays for

the manufacture of good paving brick. A paving brick is simply a brick which, through careful selection of material and through skillful manufacture, is so hard and tough that it will resist the crushing and abrading action of the traffic.

The qualities essential to a good paving brick are the same as for any other paving material, viz.: hardness, toughness, and ability to resist the disintegrating effects of water and frost. These qualities are not obtained by "vitrifying" the bricks, as is commonly supposed. Vitrification is the process

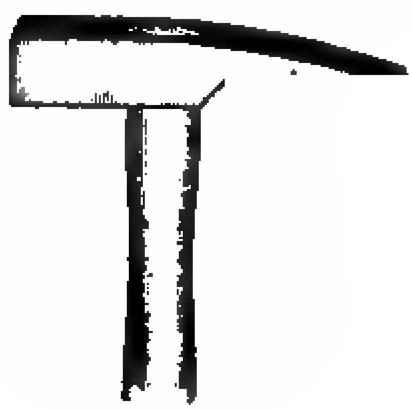


Fig. 180.—Brick Pavement laid on Sand.

of converting into glass by fusion or the action of heat, and adds nothing to the strength, but really defeats the object for which the bricks are made. The required qualities are imparted to the brick by a process of annealing, by which the bricks are burned to the point of fusion, then the heat gradually reduced until the kiln is cold. This process produces a brick of uniform texture, thoroughly compact, hard and tough, but if the cooling off is done quickly, it will produce a brittle brick that will speedily go to pieces under traffic.

There are three distinct classes of clays employed in the manufacture of paving brick—surface clays, impure fire clays,

and shales. Surface clays are almost exclusively used for the manufacture of building bricks, but are not ordinarily suitable for making paving bricks, since it is practically impossible to burn them hard enough without their losing their shape. Pure fire clay is also unsuitable for paving brick on account of its infusibility, but impure fire clay makes a fair quality of paving brick, although the process is expensive. Most paving bricks are made from shale, an impure, hard, laminated clay which has been subjected to great earth pressure, and which is widely distributed.

Brick clay.

In determining the value of a brick clay the following physical properties are important factors:

1. Plasticity.
2. Amount of water required to make a plastic mass.
3. Amount of shrinkage, both in burning and in drying.
4. Rapidity of drying and of burning.
5. Temperature of incipient and complete fusion.
6. Density before and after burning.
7. Strength of the burned brick.

The production of paving brick in 1894 was restricted within narrow limits in Pennsylvania, Ohio, Indiana, and Illinois on the west, which produced the special quality of material required for this purpose, differing entirely from that used in ordinary building bricks.

Region of production.

There are now a number of places outside these limits where paving bricks are produced in large quantities, one of the large plants being on the Hudson river at Catskill, from which have been furnished bricks for pavements in many cities and towns in the eastern and the southern states.

In the manufacture of the brick, the soft, homogeneous clay is run through rollers, to crush the lumps; it is then mixed with water and worked into a plastic mass, which then goes to the brick machine. Hard clay and shales are usually reduced to a powder, which is screened and then mixed with water. The more thoroughly the clay is worked, or tempered, the more uniform and better will be the brick.

Manufacture of paving bricks.

Paving bricks are usually made by the "stiff mud" process,

the molding being done by an auger machine which forces the tempered clay or stiff mud through a die. This gives a continuous bar of compressed clay which passes under an automatic machine that cuts the bar into bricks of the desired size. These bricks are re-pressed to make them more symmetrical in form and of better appearance, and are then placed on trucks and conveyed to the dry-house. Thorough drying facilitates the burning of the brick.

The process of burning is the most critical in the manufacture of paving bricks. They are usually burned in down-draft brick-ovens having fire pockets, or furnaces, built in their outer walls. The bottoms of the kilns are perforated to allow the gases to pass through the flues, which are beneath the floor, and which lead to the chimney. The fire passes up from the furnaces into the kilns, then down through the bricks to be burned to the flues, and thence to the chimney. At first the heat is applied slowly to drive off the water without cracking the bricks; this low heat is continued until the smoke passing off shows no further signs of steam, after which the fires are gradually increased until the temperature throughout the kiln is sufficient to fuse the bricks. This temperature is for shales, from 1500° to 2000° F., and for impure fire-clays from 1800° to 2300° F. From seven to ten days are required to raise the entire kiln to this temperature.

After the burning process is completed, the kiln is tightly closed and allowed to cool slowly, rendering them very tough. This process requires several days; it is often completed in three to five days, when seven to ten days would materially improve the product and usually would be worth the extra cost. Slow cooling is the secret of toughness, and the slower the cooling the tougher the brick.

Bricks have passed through much the same process that stone and wood blocks have passed through in being standardized as to size and shape. Experience has shown that with the proper foundation neither odd shapes, grooves, lugs, nor other devices are necessary, and that the most economical and desirable size for paving bricks is that of the standard building brick. Bricks of this size can be made more cheaply,

burned more uniformly, and those which are unsuitable for paving can be utilized for building purposes, which would be impracticable with odd shapes. The imperfect ones of odd or peculiar shape are so much waste material, and the cost of their manufacture must be added to the price of the good ones in order to protect the manufacturer from loss. Moreover, with irregular sizes and odd shapes it would be necessary for the towns employing brick pavements to keep a large stock of the different bricks on hand to make repairs, which would be expensive and troublesome.

Size and shape of bricks.

The sizes in common use are:

1. The "paving brick," measuring 8½ x 2½ x 4 inches, weighing about 7 pounds and requiring 58 to the square yard.
2. The "paving block," measuring 3 x 4 x 9 inches, weighing about 9½ pounds and requiring 45 to the square yard.

Both bricks and blocks are made with either flat sides and square edges or flat sides and rounded edges, some users claiming that the rounded edge wears better than the square edge. A variation from the flat sides is made by grooves and projections formed during the re-pressing, the object of which is to facilitate the introduction of the joint filling and to increase its holding power. The grooves are formed either by having the name of the maker in sunken letters or one or more horizontal grooves on sides and ends. Some makers form both horizontal and vertical grooves; horizontal grooves are by some considered objectionable, for the reason that the brick is liable to spall or fracture down to the groove. The projections are formed by having the name of the maker in raised letters or by either round or square buttons. The depth of the grooves and height of the projections vary with the maker from one-eighth to three-sixteenths inch.

The brick should be reasonably perfect in shape, free from marked warping or distortion, and uniform in size, so as to fit closely together and make a smooth pavement.

In the matter of testing, it is always important to have

Testing bricks.

a definite method of testing the qualities of any artificial material, since then all parties may know exactly the grade called for, and since the results obtained by different observers with different materials may be compared. This is particularly true of brick, as the clays differ greatly in quality and also as a slight variation in each step of the manufacture materially affects the result. The

Fig. 181.—Grooved Paving Blocks.

object of testing paving brick is (1) to determine whether the material is suitable for use in a pavement, and (2) to enable comparisons to be made between different classes of brick. The various methods of inspecting and testing paving brick, together with the objects to be attained by these methods, are treated fully and in detail in Baker's "Roads and Pavements."

In the construction of brick, as of other pavements, the foundation must first be considered. Each brick should have an adequate support from below, as otherwise the loaded wheels will force it downward and make the surface uneven. Various materials may be used, but experience has shown that the best foundation is a bed of concrete. On this a layer of sand is spread to secure a uniform bearing for the

bricks. The sand used for this cushion layer should be clean, moderately coarse and free from loam and vegetable matter, and from pebbles of any size that will cause the bricks to set unevenly.

Construction of pavement

The bricks should be laid on edge, as closely and compactly as possible, in straight courses across the street, with the length of the bricks at right angles to the axis of the street. At street intersections and junctions the bricks should be laid diagonally—a compromise position between the directions of the travel on the two streets. Street intersections need special care in construction, since they are exposed to the traffic of two streets. To provide for the expansion of the pavement, both longitudinal and transverse expansion-joints are used; the first are formed by placing a board templet seven-eighths of an inch thick against the curb and abutting the brick thereto. The transverse joints are formed at intervals varying between 25 and 50 feet, by placing a templet or building-lath three-eighths of an inch thick between two or three rows of brick. After the bricks are rammed and ready for grouting, these templets are removed, and the spaces so left are filled with coal-tar pitch or asphaltic paving-cement. After 25 or 30 feet of the pavement is laid, every part of it should be rammed with a heavy rammer, a plank being laid on the surface parallel to the curb to receive the blows of the rammer, or a steam-roller weighing not to exceed 5 tons may be used. After the ramming Portland-cement grout should be poured into the joints until it appears on the surface, then the whole surface should be covered with a layer of dry sand one-half inch deep.

Manner of laying bricks.

The character of the material used in filling the joints between the brick has considerable influence on the success and durability of the pavement. Various materials have been used, as sand, coal-tar pitch, asphalt, mixtures of coal-tar and asphalt, Portland cement, and various patented fillers, and there is much difference of opinion as to which gives the best results. The office of a "filler" is to prevent water from reaching the foundation, and to protect the edges of the brick from spalling under traffic. In order to meet both of these

Fig. 182.—Herring-bone Pattern.

Fig 183 —Double Diagonal Pattern.

Brick Paving at Street Intersection.

requirements every joint must be filled to the top and remain so, wearing down with the brick. Sand does not meet these requirements, as it soon washes out and leaves the edges of the brick unprotected and consequently much more liable to be chipped. Coal-tar and the mixtures of coal-tar and asphalt have an advantage in rendering the pavement less noisy and in cementing together any breaks that may occur by upheavals from frost or other causes; but unless made very hard they have the disadvantage of becoming soft in hot weather and flowing to the gutters and low places in the pavement, there forming a black and unsightly scale and leaving the high parts unprotected. The joints thus deprived of their filling become the receptacles of water, mud, and ice in turn, and the edges of the brick are quickly broken down.

The best results seem to be obtained by using a high grade of Portland cement containing the smallest amount of lime in its composition.

Durability.

Brick has been used for upwards of a hundred years in the Netherlands, and pavements laid half a century ago are still in good condition. There are several brick pavements in the United States from ten to eighteen years old which are still in good condition. The general experience with pavements formed of suitable brick, laid on an unyielding foundation, with the joints properly filled, is that they furnish a smooth and durable surface, well adapted to moderate traffic. Failures of the earlier pavements were caused by defective foundations, and the use of ordinary building bricks of the locality.

The durability of the bricks seems to depend on: 1. The clay from which they are made being practically free from lime; 2. The thorough grinding and mixing of the clay, so as to have no lumps in the bricks; 3. The bricks being thoroughly annealed.

The amount of maintenance required by a brick pavement depends upon the quality of the brick and the character of the foundation. With good bricks and concrete foundation the amount will be small, with a weak foundation and inferior bricks it will be large.

FIG 184.—Brick at Entrance to Union Station, laid in 1893. (Stone-block pavement in foreground.)

FIG. 185.—Alley Paved with Brick in 1894. Brick Pavements, St. Louis, 1901.

(From Judson's "*City Roads and Pavements.*")

Brick for country roads.

The successful use of vitrified brick for the paving of streets brought about much discussion of its adaptability to country roads in sections where good stone for macadam is not really obtainable, and it has been

FIG. 186.—Cross-section of Country Road with Earth Side Road.

used for this purpose in various parts of the country with success.

In making a brick country road in Ohio * the foundation material consisted of broken vitrified sewer pipe, broken to

FIG. 187.—Brick Country Road.

pass through a 2½-inch ring, with sufficient finer material to fill voids after rolling and to prevent the sand cushion from passing downward. Upon the foundation, and between the curbing, a layer of clean sand was placed, and on this the brick paving

* *Engineering News*, Sept. 25, 1902.

was laid. This was laid on edge at right angles to the center line of paving, and kept in even straight lines.

The brick was covered with fine dry sand, well broomed

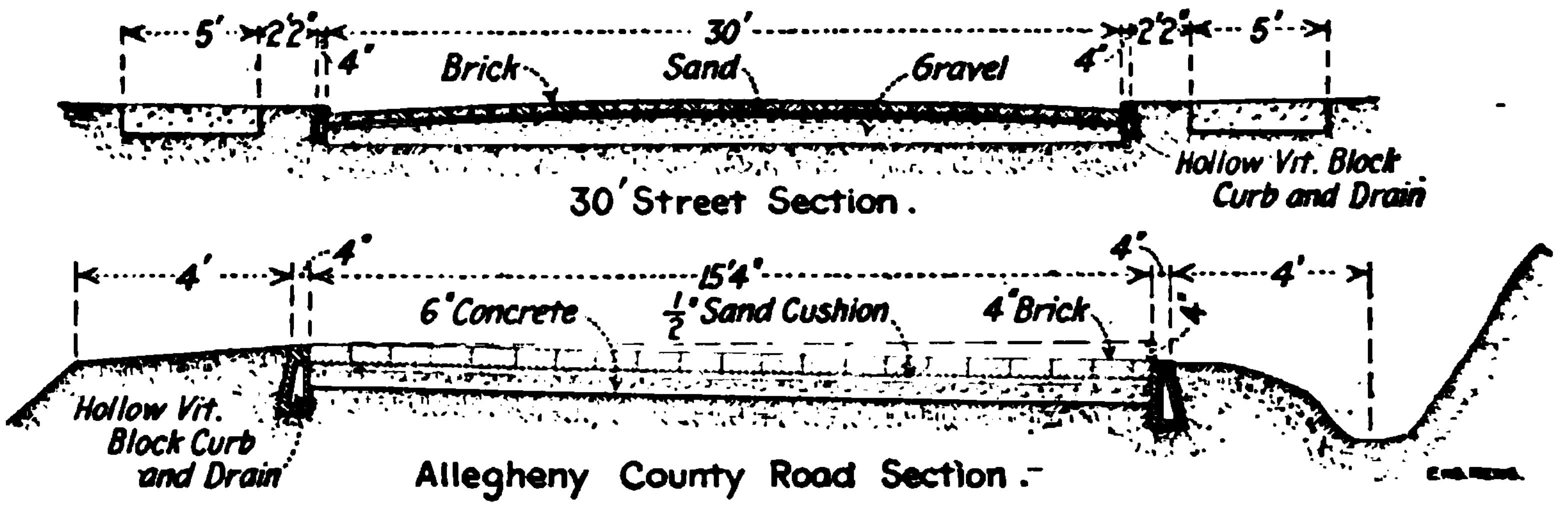


FIG. 188.—Brick-paved Street and Highway with Vitrified Clay Curbing.

in, sufficient only to fill the interstices or joints. The surface was then rolled and evenly covered with ½ inch of clean dry sand.

CHAPTER XVI

WOOD BLOCK PAVEMENTS

FOR more than seventy years, wood has been used for street paving, with little success, however, at the beginning, owing to incomplete knowledge of the materials and wrong methods in their use. It is only within the last decade that wooden pavements have been laid with any great degree of success. Wood has many qualities which especially adapt it for paving, and, with a better knowledge of the fitness of woods other than those now used, and of the effect of preservatives upon durability, it is almost certain that its use for this purpose will steadily increase.

For many years, longleaf pine was practically the only wood used for creosoted block pavements in the United States, the only important exception being in Minneapolis, where Norway pine and tamarack were laid in 1902 and have proved successful. Longleaf pine has advanced in price so rapidly as to make its use for paving very costly, and as the United States has a large variety of commercial woods, the Forest Service undertook a study of the subject, with the object of finding some woods cheaper and more abundant than longleaf pine, which would prove suitable for pavements.

Progress of wood paving.

The first use of wood for paving is said to have been in Russia, where rude blocks were laid several centuries ago. Wood was introduced into New York City in 1835–36 and in London in 1839. Continental Europe was slower to take it up. Many forms of wood pavements have been built, but the only form now in actual construction is that of chemically treated blocks. The corduroy roads of a century ago are now past history although there can yet be found, crossing swamps

on the line of the old military road built in 1812 across the Adirondack wilderness, from the Mohawk valley at Schenectady to Ogdensburg on the St. Lawrence, and to Sackett's Harbor on Lake Ontario, sections of corduroy road, which are still as sound as when laid, having been preserved from decay by the water which has usually covered them, although huge forest trees have meantime grown up in the old and abandoned roadway near at hand.*

The plank roads of a century ago are nearly gone, with the toll-gates which were the objects of their beginning and the cause of their ending; though it is of interest that there are still two plank roads leading from the westward into the city of Albany, N. Y., having five toll-gates on ten miles of road; but these relics of old days are of only historic interest, as are the majority of the many patented and forgotten forms of wood pavements which had their rise and fall thirty to forty years ago.

At that time, the chief consideration seems to have been the form of block. The large and unequal interstices between the round blocks then commonly used permitted the edges to wear off rapidly into a corduroy condition which was uncomfortable to the traveler, and which hindered both drainage and cleaning, thus making the pavement unsanitary and hastening its decay. It was to remedy this that many different forms of blocks were devised during the period between 1840 and 1870, of which perhaps the most conspicuous was the "Nicholson," patented in 1848 and laid extensively in the ten years following the civil war. This block was rectangular, which gave equal interstices; but this by no means solved the problem, and results were no better than before. Little thought was given to the kind of wood used, and as soft a wood as white pine was frequently laid. The blocks were neither seasoned nor treated with chemical preservatives, and quickly decayed. Wide joints permitted water to get under the pavement, where it was absorbed by the blocks, with the result that they swelled,

* "City Roads and Pavements," by William Pierson Judson.

so that the pavement often heaved from its foundation. Finally, the foundation was usually of untreated planks, laid directly upon earth, so that they soon decayed, while the pavement sank into ruts and holes.

Woods used for paving.

Round blocks, mostly of white cedar, were extensively laid in the Middle West, and with most success in Chicago. They made neither a durable pavement nor in any way a satisfactory one. But they were cheap and served a good purpose in tiding fast-growing cities over a critical period. There have also been laid in various cities pavements of oak, cypress, white pine, hemlock, Washington red cedar, cottonwood, mesquite, Osage orange, redwood, Douglas fir, and tamarack. In nearly all these cases the blocks were untreated, or at most dipped or boiled for a short time in tar, asphalt, or other mixture of supposed preservative value, and they failed to give satisfactory results. Untreated American red gum was tried in England, and for a time raised great hopes, but it finally proved unsatisfactory.

Some species of eucalyptus, especially jarrah and karri, have been laid extensively in England.* In London these woods have shown a life of from fifteen to twenty years, but continued use has not entirely justified the hopes first entertained for them. Their structure is too dense to permit impregnation with chemical antiseptics, without which they absorb water and swell. They wear much more slippery than most native woods, and they are not immune from decay, though because of certain antiseptic gum-resins which they contain they are more so than any untreated native

* Jarrah (*E. marginata*) and Karri (*E. diversicolor*) are very dense and hard woods, growing plentifully in Western Australia. Jarrah is bright to dull red in color; short grained; free splitting, breaking with a clean fracture, and burns with a black ash. When seasoned, it has a specific gravity of 1.01 and it absorbs about 10 per cent of moisture when immersed forty-eight hours, as against the absorption by most soft woods of 20 to 25 per cent. Karri is very similar in appearance to jarrah but somewhat lighter in color, is interlocked in the grain and is difficult to split; it splinters in breaking and burns with a white ash. When seasoned, it has a specific gravity of 1.12, and absorbs about 7 per cent of water when immersed forty-eight hours.

This machine cuts 240,000 blocks per day. The upper half of the machine has been raised in order to show the circular saws and the planks of wood entering the machine.

FIG. 189.—Machine for Cutting Wood Paving Blocks.

woods. In England, however, they are still used. Jarrah blocks were laid on Twentieth street, New York City, in 1895, but were removed in 1904. The cost of this pavement was about $5.00 per square yard, which would exclude these woods from extensive use in America even should they make a better pavement than our best creosoted native woods, which is not likely.

After the failure of untreated native woods, attention was turned to wood preservatives. For the treatment of wood paving, the tendency has been to narrow down to the use of

Fig. 190.—Method of Cutting Planks from Logs.

one material, the dead oil of coal-tar, commonly called creosote, either pure or in mixture with resin, pitch, or other materials. Creosoted southern pine paving blocks are said to have been laid in the United States at Galveston, Tex., as early as 1873. This pavement, in spite of being laid on a foundation of sand, gave satisfactory service for nearly thirty years, and was destroyed only by the great flood of 1900. But this good beginning was not at once followed up, and only within the last ten years has the matter received systematic attention in this country.

The success of the modern wood block pavement is due to several things. The wood is carefully selected, both as to

kind and quality; it is cut accurately into rectangular blocks, is put through seasoning processes and is preserved from decay by chemical means. Its liability to absorption of water and the consequent expansion and contraction of the pavement are reduced to a minimum. The blocks are then laid with the grain vertical, over an accurately surfaced cushion on a solid foundation of cement-concrete. They are close-jointed, and, in the best practice, the joints are made water-proof. The result is a pavement having the advantages of:

Qualities of treated wood pavement.

1. Comparatively good foothold for horses.
2. Smoothness and resiliency, offering less resistance to traction than stone and slightly more than asphalt.
3. Suitability for all classes of traffic.
4. Adaptability to grades up to five per cent.
5. Even wear and moderate durability.
6. Cleanliness, yielding no mud and but little dust.
7. Moderate first cost.
8. Comparative noiselessness.

Its principal disadvantages are:

1. Slipperiness under certain weather conditions.
2. Difficulty in opening to gain access to underground pipes, and the necessity of removing a rather large surface for this purpose and of leaving it for some time after being repaired before traffic can be resumed upon it.
3. In spite of its many advantages it is claimed by many to be unhealthy.

The opinions of engineers of a number of American cities as to the qualities of treated wood block in comparison with other paving materials, obtained by the Forest Service of the U. S. Department of Agriculture, have already been presented in tabulated form on page 32.*

The cost of creosoted wood pavement in the United States

* In the course of this inquiry much information was obtained in relation to creosoted wood block pavements, which has been published under the title "Wood Paving in the United States," by C. L. Hill, Forest Assistant, Circular 141, Forest Service, U. S. Department of Agriculture.

has varied from $2.40 to $3.50 per superficial square yard laid. As shown in Table IV (page 32), the average cost per yard for all cities which reported was $3.10. The basis of judgment upon a pavement should be the returns upon its total cost for the life period, considered as an investment. In Europe this is done, but in the United States the first cost is in most cases given undue weight. For a pavement such as creosoted wood, the first cost of which is high, this method is very unfair and reduces the pavement's total standing much below its service value. Table IV takes into account the factors of pavement value more systematically than do other methods used in this country, but it does not provide a basis of investment returns. A better way would be to express the cost item in terms of total annual charge; this would take into account the factor of durability, and would remove it from separate listing in the table. The result would be much more consistent and accurate.

Cost.

Disregarding cost, and basing the comparison upon service qualities only, the difference in favor of creosoted wood is materially increased. Wood ranks very high in every quality listed, except in freedom from slipperiness and, to a less extent, in durability. It is highest in those qualities which contribute to the acceptability of the pavement.

Service.

There is in the United States almost no wood pavement of the modern kind which has yet been down long enough to show its durability. The values assigned by the engineers to durability are, therefore, based principally on general impressions and inference from European experience. There are, however, a few cases in the United States which offer pertinent evidence.

Durability.

In Baltimore, Md., in the summer of 1901, there were laid several adjacent strips of experimental pavements, including sheet asphalt, creosoted wood, and several kinds of brick. After five years' service, and after passing through the great fire, the wood was in better condition than any of the others.

On Michigan avenue, Chicago, is a creosoted longleaf pine pavement, laid in the year 1900. Adjoining it an area of

asphalt block was laid at the same time. In 1905 the asphalt blocks were removed and replaced with wood. In the five years the asphalt had worn down on an average one inch, but very unevenly, so that ruts had formed and the blocks were badly rounded. The wooden blocks during this time had worn off only one-eighth of an inch, and the surface, except for a badly constructed gutter at one point, was still perfectly smooth and of even grade.

In 1902 the Metropolitan Street Railway Company, of New York City, decided to experiment with creosoted wooden blocks for paving between its tracks. A small area of longleaf pine was laid on Hudson street, the wood being flanked at either end by granite, the material hitherto used. At the point selected there is a very heavy trucking traffic from the North River wharves, and the stresses on the pavement, where the trucks run with one wheel just outside the car rail, are so great that the granite begins to show a rut in six months, and is renewed almost annually. At the end of four years the wood, though showing a heavy rut, was still sound and in position and good for at least one more year. The granite on either side had been renewed three times during the four years.

These few examples can not of course be regarded as final as there have been instances in which creosoted blocks have given poor results, caused principally by improper preservative treatment of the wood or faulty construction of the pavement. The many cases of successful pavement indicate that such errors are responsible for the failures which have occurred, and that wood block pavement, properly prepared and laid, should be credited with a durability greater than 14 in a scale which rates asphalt blocks at 14 and whose standard is granite at 20, as in Table IV.

Nor is this conclusion invalidated by the fact that European wood pavements, as compared with granite, show a durability relatively less than this. American longleaf pine is a harder, denser wood, and has greater resistance than the European pine used for paving. While wood preservation has in general, attained a greater perfection in Europe than

in America, yet American creosote treatment of wood paving blocks is more thorough than the European.

Tractive resistance.

Resistance to traction and freedom from slipperiness are opposing qualities, so that gain in one is likely to be made at the expense of the other. Table IV shows creosoted wood and the asphalts equal in the matter of tractive resistance, while on the score of freedom from slipperiness, wood is placed below both of the others. This is hardly consistent, as recent experiments indicate that in these respects American sheet asphalt varies considerably with the temperature. In cold weather it is exceedingly hard, smooth, and slippery, but in hot weather its softening causes it to cling to the tires and increases its tractive resistance to a point greatly beyond that of wood.

Of two neighboring cities in which the conditions affecting the pavements are practically the same, the engineer of one believes wood to be more slippery than asphalt, while the engineer of the other believes asphalt to be more slippery than wood. This is but an example of the difference of opinion which exist on this point, due in large measure to the variation in the asphalt under different conditions. In both tractive resistance and slipperiness wood appears to be more constant than sheet asphalt. In hot weather, therefore, wood is likely to be more slippery than asphalt, while in cold weather it is likely to be less slippery. Wood and asphalt are both most slippery when slightly wet. Between different kinds of wood there may also develop considerable difference in slipperiness. Experience has shown that Norway pine wears much less slippery than longleaf.

The maximum gradient recommended by the majority of engineers for either pavement is from two to five per cent, according to the conditions of climate and traffic.

Quality of wood used for paving.

The problems to be met in wood paving are (1) problems peculiar to wood and wooden pavements, and (2) problems of construction common to all pavements. One of the drawbacks in the use of wood for paving has been a lack of knowledge of the wood itself. For example, sapwood has always been thought

to be both weaker and more subject to decay than heartwood. It is rigidly excluded from most wood paving specifications, and all-heart blocks demanded. The inclusion of sapwood undoubtedly caused the untreated blocks of former years to wear unevenly and to decay quickly. But the preservative treatment now applied provides against this decay. Recent tests show that under equal conditions of moisture content, the sapwood of many species is as strong as the heartwood. It is usually less strong because wood is rarely used under conditions where the moisture content of the sapwood is as low as that of the heartwood. Preservative treatment, with proper previous seasoning, reduces the moisture content of each to an approximately even minimum, and the heavy charge of oil now customary in American wood paving treatment prevents subsequent absorption of moisture, beyond a small per cent. After five years' service, there is no discernable difference in wear between the heart and the sap portions of unseparated Norway pine blocks laid in Minneapolis.

Wood preserving methods.

A wood pavement fails through wear and decay, and many methods have been invented to prevent the decay and increase the durability of the timber. Timber thus treated is used for piles, railroad ties, and other purposes, as well as for paving blocks. Experiments in the preservative treatment of wood date back, as far as is known, to 1657, when Glauber recommended treating wood with tar. Since that time an almost endless list of substances has been experimented with, but the methods that have stood the test of time and are at present in use, consist of injecting different kinds of antiseptics into the pores of the wood.

The results to be obtained by preservative treatment for wood paving, are:

1. Preservation from decay.
2. Mechanical filling of the pores, to prevent the absorption of fluids, which further accomplishes:
   a. Elimination of expansion,
   b. Increase of resistance to wear,
   c. Maintenance of sanitary value.

The methods of treatment best known are those called:

"Kyanizing," using corrosive sublimate,

"Burnettizing," using a solution of chloride of zinc,

"Boucherizing," using sulphate of copper,

"Creosoting," using creosote oil, which is the method most used in the United States.

Creosote oil seems to meet the requirements better than any other preservative commonly used. The other preservatives are mostly water solutions, which are easily leached out of the wood and thus lose their preservative effect. Moreover, being themselves largely composed of water, they do not prevent expansion in the blocks, do not increase their resistance to wear, and do not maintain them in a sanitary condition.

Creosoting.

Creosoting has generally been supposed to weaken timber. The results of experiments conducted by the Forest Service indicate, however, that the creosote itself does not lessen the strength of timber, but that this result in practice has been due chiefly to certain methods used in the impregnation.

The Rush Street bridge in Chicago, Ill., is said to carry a traffic as heavy as any in the city. It has two 20-foot roadways, which were paved in 1899, one with creosoted longleaf pine blocks, the other with uncreosoted blocks. The creosoted pavement, after a service of seven years, was still in good condition and was expected by the chief engineer to last several years more, while the uncreosoted pavement had to be renewed in 1902.

The explanation of these facts lies in the antiseptic qualities of the creosote and its physical action in filling the pores of the wood and decreasing its absorption of water. Every pavement is wet a large part of the time, and wood, when saturated with water, has generally less than 40 per cent of its kiln-dry strength. The creosoting treatment, by lessening the absorption of water, maintains the strength at much nearer the dry-wood value, and thereby increases the actual service strength.

This action is most effective only when the wood is well

seasoned before being creosoted. In the United States most creosoters attempt to dry the wood by applying steam and vacuum. Recent experiments have shown that wood will, except when very green, weigh more after such treatment than before. That is, by this process, it will take up moisture rather than lose it, which would destroy any possible gain in strength through the creosote treatment. Not only is the steaming in most cases valueless, but if carried too far, as it often is, it seriously injures the wood. Natural seasoning, which in Europe is used almost entirely, would certainly contribute to increased excellence of results in the United States.

The common opinion among engineers in regard to the creosoting of wooden pavements is expressed by a prominent paving engineer, who says:

"For wood paving creosoting is only of contingent value. If the traffic is heavy enough to wear out the pavement before it decays, which it will do on most city streets, it is a waste of time and money to creosote the blocks. Creosoting is only economically desirable, therefore, when the traffic is so light that decay will reduce the block before it fails from wear."

This would be true if creosoting treatment had no effect on wood pavements other than the preservation of the wood from decay. But creosoting effects, through the increased service strength of the blocks, an additional and quite different gain. It is believed that there is already enough evidence, such as that offered by the Rush Street Bridge, to overthrow the traditional doctrine of the limited value of creosote preservative treatment for wood paving.

Creosote is an oil of tar from which the ammonia has been expelled. Its effect on the wood is to coagulate the albumen and thereby to prevent its decomposition, and also to fill the pores of the wood with a bituminous substance which excludes both air and moisture, and which is obnoxious to the lower forms of animal and vegetable life.

In the United States, the timber for paving purposes is impregnated by the vacuum-pressure method. Closed cylinders, usually about six feet in diameter by about 100 feet in

length, are used. The amount of oil usually injected into the wood is sixteen pounds per cubic foot, though in some cases it reaches twenty-two pounds. To many engineers this has seemed an unusually large amount, constituting an item of expense in the already high cost of wood paving which might profitably be reduced. But the necessity for the prevention of moisture absorption under conditions more exacting than those in which almost any other creosoted wood product is subjected, makes imperative the impregnation of wood paving blocks with an amount of oil per cubic foot greater than that ordinarily given to railroad ties or construction timbers. The tendency is toward heavier charges than the reverse, to secure for wood pavement a service so greatly enhanced as to yield better returns upon the investment, even at the higher cost.

Impregnation of timber.

In Paris the blocks are usually impregnated by merely soaking for a short period in an open tank, and the amount of oil injected per cubic foot is small. The life of Paris pavement so treated is from six to fourteen years only, according to the traffic; and, because of the small impregnation, expansion in the pavements is large and calls for the laying of longitudinal courses of blocks at the curbs, which are removed as it becomes necessary. The vacuum-pressure method for the treatment of wood paving blocks, is of comparative recent introduction. This is the reason for the statement that American creosote treatment of wood paving is superior to that of Europe. The excellence of European wood pavements, despite this defect, is largely due to better construction, maintenance and repair.

The creosote as ordinarily used is an effective preservative in itself, but it tends to form an emulsion with water, and is in time washed out by rains, and it also tends to evaporate half to three-fourths on exposure to the sun and the weather. To avoid these defects has been the object of two recent modifications of the treatment; one called the "kreodone-creosote," and the other the "creo-resinate" process.

This consists in impregnating the seasoned selected blocks under pressure with ten pounds per cubic foot of an oil derived

from creosote oil, possessing the original preservative proper ties with a longer endurance, and also having the effect of forming a varnish-like film or coating on the outer surface of the wood, protecting it from the elements. The seasoned blocks are sterilized by subjecting them to dry heat of 240° Fahr., for

Kreodone-creosote process.

FIG. 191.—Kreodone-Creosote Wood-block Pavement, Meridian Street, Indianapolis, in Progress of Construction.

(*From Judson's "City Roads and Pavements"*)

eight hours. The kreodone-oil is then forced into the fibers of the wood, under a pressure of seventy pounds per square inch maintained for two or three hours, or until twelve pounds have been absorbed by each cubit foot of the wood.

The special features of this process are the preliminary treatment in dry heat to kill the germs of decay, and the

mixing with the creosote of 50 per cent of melted rosin which is forced into the fibers with the creosote, where it solidifies and seals the pores of the wood and prevents the evaporation of the creosote or its displacement by water, which can find no entrance, so that the pavement does not swell and heave when wet.

Creo-resinate process.

It is claimed that this process increases the density of the wood and also its resistance to impact and abrasion over either untreated or creosoted wood. It is further claimed that the more porous blocks take up more of the creo-resinate mixture than the denser ones, and consequently increase in density and strength to a greater degree, the process thus making the blocks more uniform in quality.

Foundation and cushion.

For the most satisfactory service, wood-block pavement requires a concrete foundation. This is usually made from 5 to 6 inches thick, although some engineers reduce it to 4 inches on lightly traveled residence streets. As a top cushion for the foundation either Portland cement mortar or sand is used, the former being considered the better. The bearing for the blocks is permanent, and, if carefully surface-trued, can be made as even as desired; and if the grout is mixed slightly damp and the blocks laid in it immediately, it provides equally as good a compensation for minor inequalities in the height of the blocks as sand does. If tar can be used, a better method of accomplishing the same object is to mix the grout in the usual way and let it thoroughly set, after which a coating of tar should be applied and the blocks bedded in it. This is the method oftenest used in Europe. Sand makes a satisfactory cushion where the slope is negligible and the foundation is solid. It is sometimes preferred on the ground of greater elasticity and power of accommodation, and it has the merit of being cheaper than cement. On a gradient, however, if water, by any possibility, gets under the blocks, it is likely to carry the sand to the bottom of the slope and seriously derange the pavement. On bridges, also, if there is much crown on the roadway, the vibration of the structure is likely to shift the sand from the center of the crown toward the gutter. For bridges

Fig. 192.—Creo-resinate Wood-block Pavement, Beacon Street, Boston, in Progress.

(From Judson's "City Roads and Pavements.")

the usual practice is to lay the blocks directly on carefully creosoted planking.

Blocks.

The blocks should be rectangular, 3 inches wide, 4 to 6 inches deep and 9 inches long. They should be cut from sound timber, free from sapwood, and should be rigidly inspected, especially as to imperfections of sawing, as to knot-holes, decay, or defective corners or edges, as to squareness of the angles, and as to thoroughness of impregnation. Voids due to imperfections in any of these respects often can not be properly filled by the joint filler, and are very detrimental to the pavement. In European practice no variation greater than one-sixteenth inch in any dimension of the blocks, and no measurable variation in the depth, are allowed. There the blocks are also required to be kept carefully protected from sun and weather after treatment and until they are laid. Deterioration from checking, which in America is often considerable, is thus prevented.

Exclusion of second growth material from wood-paving specifications is immaterial, except in so far as young trees contain a greater proportion of sapwood than older trees; and, since sapwood is separately provided for in most cases, the specification prohibiting second-growth timber could well be abandoned. Sapwood is entirely excluded by most wood-paving specifications. Under existing market conditions, however, it is quite impossible to obtain strictly all-heart southern pine such as the specifications demand. The true longleaf pine* has usually so narrow a sapwood that it could be neglected without danger to the life of the pavement. In loblolly pine the sapwood is often very wide; but this is one of the species for which it has been proved that the

*The terms "longleaf" and "shortleaf" pine are descriptive of qualities of Southern yellow pine, rather than of botanical species. Thus, "shortleaf pine" would cover such species as are now known as North Carolina pine, loblolly pine and shortleaf pine. "Longleaf pine" is descriptive of quality, and if Cuban, shortleaf, or loblolly pine is grown under such conditions that it produces a large percentage of hard summer wood, so as to be equivalent to the wood produced by the true longleaf, it would be covered by the term "Longleaf Pine."

sapwood under equal conditions of moisture content is as strong as the heartwood. Therefore, when effective seasoning of paving material can be assured before the creosote treatment, the prohibition of sapwood in southern pine material is needless, and might well be omitted from specifications.

A more pertinent specification would be one excluding fast-grown timber in pine paving-block stock—say all showing less than eight rings to the inch—since it is the porous wood resulting from fast growth, rather than the presence of sapwood, which unfits timber for this use.

The angle at which the courses are laid in wood pavement is a matter of some importance. The most obvious angle

Fig. 193.—Different Angles used in Laying Pavement.

is that of 90° with the curb, which takes the courses straight across the street. Probably the greater part of the wood-block pavement in the United States is so laid. But this angle permits the calks of horses' shoes to strike in a direct line with the joints, and subjects the pavement to a wear and tear which may largely be avoided by laying the courses at an oblique angle. Moreover, if expansion occurs, transverse as well as lateral expansion joints are necessary to provide against it, and transverse joints of this character in wood pavement are always undesirable. With the courses laid at an oblique angle, the thrust of the pavement in case of expansion will impinge in both directions upon the curb, and the transverse expansion joint may be entirely dispensed with.

Angle of courses.

The oblique angle which most naturally suggested itself

was 45°, and a large amount of pavement has been so laid. There has, however, developed an objection to this angle. Transverse expansion in wood takes place in two directions, tangentially to the rings of annual growth, and radially to them. Of these the transverse expansion is greater than the radial. As will be seen from the accompanying diagram of the common method of sawing lumber, a majority of blocks have their long axes in a plane tangent to the annual rings of the wood, or at least nearer to that plane than to the radial. Therefore the force due to tangential expansion will be exerted chiefly in the direction of the courses in the pavement, and the lesser or radial force will be exerted at right angles to that direction. The angle of 45° does not compensate the differential expansions in the wood, and in uncreosoted or poorly creosoted pavements twisting strains have developed.

The angle between 45 and 90° from the curb has therefore been bisected by some engineers, making the angle with the curb consequently 67½°. This solution of the problem was an entirely empirical one, but it seems to avoid the difficulties experienced with the previous angle.

Expansion joints.

All untreated wood blocks absorb water and expand to a considerable extent, and treated blocks expand appreciably. Unless this expansion is provided for it is likely to disturb the curbs or lift the blocks from their foundation. Transverse expansion joints are altogether bad. The objection is the same as that against wide body joints, that the filler wears away faster than the blocks, leaving a depression which permits the edges of the blocks to wear off and destroys the smoothness of the pavement. Expansion joints should be longitudinal at the curb, with a longitudinal course of blocks between the expansion joint and the body of the pavement, and between each expansion joint, if more than one is used. The most satisfactory results have been obtained by leaving the expansion joint open for a few days, when it may be filled with sand, or if pitch is used to fill the body joints, with sand up to within one-half inch of the surface, and the remainder with pitch.

The customary width of this joint is from 1½ to 2 inches on each side of a 60-ft. roadway, though in some places 3 inches is allowed, and this is filled up with either a hot mixture of pitch and creosote oil, sand, or clay.

Considerable creosoted block pavement in the United States has been laid without any expansion joints, and where the creosoting of the blocks, as well as the laying of the pavement, has been well done, little serious trouble has been experienced; but it is safer to provide expansion joints.

There is some uncertainty among engineers as to the best joint filler for wood pavement. One prominent engineer gives it as his opinion that if the traffic is heavy, so that

Fig. 194.—Cross-section showing Joint Filling.

Filler.

the joints between the blocks will be speedily obliterated, a sand joint may be used as well as any other, and it is considerably cheaper than the others. But if the traffic is not heavy enough to obliterate the joints, sand permits the ingress of water, and gradually works down and leaves a space to be filled with debris, which lowers the sanitary value of the pavement. Cement mortar as a filler is waterproof at first, but it soon crumbles and becomes then no better than sand. Besides, it is too inelastic and increases the noise from the pavement.

Except under heavy traffic, therefore, some substance like coal-tar pitch is preferable. But pitch has this disadvantage —that a grade which will not crack under the cold of winter is likely to become soft and sticky in the heat of summer.

Care is necessary to select a quality which shall avoid these difficulties. There are some proprietary preparations on the market which offer specific advantages as fillers, since their range of stability is greater than that of pitch, so that they become neither brittle nor sticky, at least under natural conditions in a temperate climate. To fill the joints effectively, pitch should be heated to about 300° F. when applied, so as to insure perfect fluidity.

Top dressing.

The top dressing for wood pavement is usually of screened, sharp sand or of finely crushed stone, about one-half inch in thickness. This is allowed to remain on the pavement about two weeks, or longer when convenient. The top dressing benefits wood pavement in several ways. A certain amount is ground into the surface of the blocks and both increases their resistance to abrasion and reduces slipperiness. If sand has been used for a joint filler the surface sand keeps the joints filled as they settle, and if the joint filler is pitch the sand takes up any surplus pitch from the surface of the blocks and leaves the pavement cleaner than it would without it. A subsequent occasional light sanding is a distinct advantage to the pavement.

Repairs and maintenance.

In the care of the pavement after it is laid American cities fail more seriously, perhaps, than in any other particular. Once laid, the pavement is often expected to take care of itself without any further attention. This is often due to causes beyond the control of the engineer; but the fact remains that such treatment may go far to defeat the best manufacture and construction. In Europe wood pavements are cleaned with regularity and care. They are frequently flushed with water and are never allowed to dry out, as they often do to an excessive degree in the summer droughts in America. They are sanded at regular periods, as well as on any occasions of special slipperiness. Most American cities appear to consider that such maintenance as is given in Europe is impossible here. A few, however, do give adequate care to their pavements, and it is believed that for many others greater attention in this direction would be a paying investment rather than an expense.

Practically the only repairs required aside from replacing blocks taken up to get at water and gas pipes, etc., is to remove soft or decayed blocks and to insert new ones. The hole caused by a single decayed block is speedily enlarged by the impact of wheels dropping into the depression.

CHAPTER XVII

ASPHALT PAVEMENTS

Nomenclature.

ASPHALT exists in various forms over widely distributed parts of the earth, and has been in somewhat common use for different purposes since the dawn of history; consequently the terms employed to designate it have been varied. The following definitions are generally accepted and are sufficiently exact for ordinary purposes:

Bitumen.

"Bitumen is a natural hydrocarbon mixture of mineral occurrence, widely diffused in a variety of forms which grade by imperceptible degrees from a light gas to a solid, sometimes found in a pure state, but usually intermixed with organic and inorganic matter. The bitumen series includes the following, in order of their density: Natural gas, natural naphtha, petroleum, naphtha (at ordinary temperatures soft and sticky), asphalt (at ordinary temperatures stiff and non-sticky), glance pitch (dry and brittle).

Asphalt.

"Asphalt is a general name for the solid forms of the natural mineral bitumen. Asphalt is distinguished from coal in being soluble in bisulphide of carbon and in benzole. Coal, peat, etc., are called pyro-bitumens because they yield an artificial bitumen by distillation. Asphalt is usually found associated with various mineral and organic substances. Asphalt is sometimes popularly called mineral pitch and mineral tar; and different varieties of asphalt are called grahamite, albertite, gilsonite, wurtzelite, imitatite, turrellite, etc.

"The term 'asphalt' is the English equivalent of 'asphaltum,' the Latin form. Asphalt and bitumen are frequently used synonymously, but usually in paving literature bitumen is employed to designate the valuable hydrocarbon compounds in the native asphalt.

"*Crude asphalt* is the native mixture of bitumen, sand, clay, water, organic matter, etc.

"*Refined asphalt* is the native mixture after it has been freed wholly or in part from water and organic and inorganic matter by being heated. Commercial refined asphalt contains considerable earthy matter; in fact, commercial refining consists virtually in driving off the water and volatile oils, and incidentally in removing a little earthy matter.

"*Rock asphalt* is a limestone or sandstone naturally impregnated with asphalt. Rock asphalt is the principal form of asphalt used in Europe for paving purposes and is usually there designated as 'asphalt.'

"*Asphaltic* or *bituminous limestone* is a limestone naturally impregnated with asphalt.

"*Asphaltic* or *bituminous sandstone* is a sandstone naturally impregnated with asphalt.

"*Compressed asphalt.* In Europe, particularly in France, a rock-asphalt pavement is frequently referred to as being made of 'compressed asphalt.'

"*Asphalt mastic* is a term frequently applied to refined asphalt, particularly to that obtained from bituminous rocks, and is usually in the form of cakes, which are melted and mixed with sand and used for making pavements and sidewalks.

"*Asphaltic cement* is refined asphalt which has been mixed with some solvent to increase its plasticity, adhesiveness and tenacity.

"*Asphalt pavement* is a pavement composed of sand or pulverized stone held together by asphalt. In America an asphalt pavement is ordinarily understood to be a comparatively thin layer of sand held together by asphalt laid upon a bed of hydraulic cement concrete; but in Europe the term asphalt pavement is understood to be a comparatively thick layer of asphaltic limestone or asphaltic sandstone with or without a hydraulic concrete base.

"*Asphaltic concrete* is broken stone bound together with asphaltic cement." *

* "Roads and Pavements," by I. O. Baker, p. 385.

In going back to the earliest times in which asphalt is known to have been used it is necessary to refer to the mineral pitch, or bitumen, as being the material quoted. The first use of asphalt spoken of was the cementing in the erection of the Tower of Babel; next we read that Noah pitched the Ark within and without ("*bituminabis cum bitumine*"), and also in Genesis we read, "*Et asphaltus fuit eis vice cimenti.*"

Historical.

Felltham wrote in the beginning of the seventeenth century of the "Bituminated walls of Babylon"; the source of its supply, the fountains of Is, on a tributary of the Euphrates, still yelds asphalt.

Xenophon speaks of the Median Wall as being built of "Burnt brick laid in asphalt," and Diodorus Siculus describes the process of laying the walls of Nineveh with material from the same source. He says: "In order to bind the bricks they were covered with a layer of asphalt, instead of simple tempered clay, and were arranged in courses, and between each thirteenth course a bed of reed canes was introduced." The burning of Sodom and Gomorrah has been attributed to the accidental ignition of petroleum or bitumen, but the word petroleum not having been known to ancient writers, the legend probably refers to maltha or bitumen. Other ancient authors mentioning asphalt were Herodotus, Aristotle, Strabo, Pliny, and Homer.

The Egyptians spread bitumen upon the bandages wound around their mummies, and its wonderful preservative properties in this connection can be seen in the museums of to-day. Asphalt was also used by the Egyptians in the foundations of the Pyramids, and for the coating of the external and internal walls of the ground floors of houses, and in the construction of cisterns, silos, and other work where waterproofing was necessary.

It will be seen, therefore, that from before the time of the Deluge, asphalt has been used and referred to, but there is no record of its use for street paving until 1838, and not until 1854 was it employed to any great extent. The laying of macadam roads in Val de Travers, Canton of Neuchatel,

Switzerland, led to the discovery that the brown bituminous limestone rock, found in the district, under traffic and the summer heat became welded into a continuous sheet.

In 1854 some streets in Paris were paved with this material, and it was introduced into London in 1869. The success which attended these early pavements led to its extensive use throughout Europe, and to its introduction into America.

In 1870 the first sheet asphalt pavement in this country was laid in Newark, N. J., in front of the City Hall. In 1873 a small piece was laid in Fifth Avenue, New York, and a few other experimental sections were laid; but its first test on a large scale was in 1876 on Pennsylvania Avenue in Washington, D. C. Preceding 1882, outside of Washington, D. C., there were not more than half a dozen streets in this country paved with any form of asphalt; but since that date, asphalt pavements have increased so rapidly that they now rank first in extent of use and in satisfactory qualities.

These pavements were at first made of materials imported from Europe, but the great cost involved made the pavement so expensive as to induce American inventors to seek to manufacture a material having similar qualities. The result was the introduction of many substitutes and imitations, the majority of which proved defective. The cost of the imported material and the failure of the substitutes directed attention to the deposits of natural bitumen on the island of Trinidad, and experiments were made which demonstrated the possibility of making a mastic with this bitumen as its cementing material, as strong, elastic, and durable as that imported from Europe; but it was only after some years that this process was introduced and made a commercial success.

The difference between the asphalt pavements of Europe and those of America is due to the character of the materials.

European and American pavements.

The former are composed of limestone rock naturally impregnated with bitumen, while the latter are composed of an artificial mixture of bitumen, limestone, and sand. The limestone in the European pavements becomes hard, smooth, and slippery under

traffic, and is thus objectionable for general use in frosty latitudes. The granular nature of the sand used in preparing the Trinidad asphaltum diminishes the tendency to wear smooth and materially lessens the slipping of horses.

Many deposits of bituminous rock are found in the United States, but they have been used only to a limited extent, the principal sources of supply at present being the Island of Trinidad, Bermudez, Venezuela, and California.

The cost of preparing the different varieties of asphaltum for street pavement is nearly the same; and as all appear to be about equally durable, the exclusive use of any one of them is due merely to local conditions.

An artificial asphalt pavement consists primarily of:

1. A foundation of hydraulic cement concrete, or an old pavement of cobblestones, granite blocks, bricks, etc.
2. A binder course composed of broken stone and asphalt cement.
3. A wearing coat 1½ to 2 inches thick composed of asphaltic paving cement mixed with sand.

Artificial sheet asphalt pavement.

The advantages of this pavement are:

1. Ease of traction.
2. Comparative noiselessness under traffic.
3. Impervious to water.
4. Easily cleaned.
5. Produces neither mud nor dust.
6. Pleasing to the eye.
7. Suitable to all classes of traffic.
8. No vibration or concussion in travelling over it.
9. Expeditiously laid, causing little inconvenience to traffic.
10. Openings to gain access to underground pipes easily made.
11. Durable.
12. Easily repaired.

The defects are:

1. Slippery under certain conditions of the atmosphere.
2. Disintegrates if excessively sprinkled or otherwise subjected to constant moisture, although asphaltum is impervious and insoluble in either fresh or salt water.

FIG. 195.—Carroll Street, Brooklyn, N. Y., before Covering Cobble Pavement with Sheet-asphalt in 1900.

(*From Judson's "City Roads and Pavements."*)

Fig. 196.—Carroll Street, Brooklyn, N. Y., after Paving with Trinidad Sheet-asphalt in 1900.

(From Judson's "City Roads and Pavements")

3. Becomes soft under traffic in extreme heat and presents a wavy surface, and under extreme cold may crack and become friable.
4. Not adapted to steep grades.
5. Necessity of quick repairs. The material has little coherence, and if from irregular settlement of the foundation or local violence, a break occurs, the passing wheels rapidly shear off the sides of the hole. This is prevented in some cities by the constant attention of workmen who traverse the streets with a light repairing outfit, and wherever a defect is observed it is patched at once and so effectually that the spot cannot be distinguished.

Asphaltum itself is one of the most imperishable substances in nature. Among the oldest monuments of human industry that survive are constructions of asphalt. With asphalt pavements the systems adopted for maintenance render it difficult to ascertain the actual life of the pavement under traffic. They are repaired immediately they need it, and as each repair is so much new material laid, the whole surface is really relaid in the course of years. Experience has shown that asphalt will last without extensive repairs from four to six years, and that in the course of ten years, the entire surface will have been renewed.

Durability.

Asphalt is to a certain extent elastic and does not begin to wear until this elasticity is overcome by thorough compression. This is the case with no other paving material; stone and wood begin wearing from the day traffic commences. Under ordinary traffic it may be estimated that it will take two years to complete the compression of asphalt, and the weight of a square foot of this pavement will at the expiration of that time be nearly the same as on the day it was laid, though the thickness is reduced during the first two years as much as it will be in the following eight.

The extent to which the thickness has been reduced is said to be as much as one-fourth the original thickness. A pavement in Paris which had lost more than one-fourth of its thickness was found to have lost only 5 per cent of its weight

after sixteen years' use, and the pavement in Cheapside, London, after fourteen years' use, shows a reduction, where not repaired, from its original thickness of $2\frac{1}{4}$ to $1\frac{3}{8}$ inches.

Construction of the Pavement

The sheet asphalt wearing surface has no power in itself to support the traffic, so that a solid unyielding foundation

FIG. 197.—Laying Bituminous Foundation, Rome, N. Y.
(From Judson's "City Roads and Pavements.")

is indispensable, otherwise the weight of the traffic would crush it. If the street has never been paved, the base of the proposed asphalt pavement is made of hydraulic cement concrete 4 inches thick for light traffic, or 6 inches for heavy city traffic.

Foundation.

Sometimes the asphalt is laid upon a bituminous concrete, the advantage claimed being that the asphalt adheres more firmly to it than to the hydraulic concrete and prevents weather cracks and waves. It is also less expensive, but repairs

are more difficult. This form of foundation has never been common and is now very little used.

With cement concrete, the bond between the foundation and the wearing surface is not very great, hence it is very easy to strip off the surface in case repairs are necessary; but it sometimes slips on the foundation, and rolls into waves and irregular surfaces, and sometimes cracks with sudden and great changes of temperature. A cement concrete foundation must be set and thoroughly dry before the asphalt is laid, as the best asphalt laid in the most skilful manner on first-class but damp concrete will rapidly go to pieces. When the hot asphalt is applied to a damp surface the water is immediately sucked up and turned into steam, which tries to escape through the heated material; the result is that coherence is prevented, and, although the surface of the asphalt is smooth, the mass is really disintegrated from underneath by the water. As soon as the pavement is subjected to the action of traffic, the fissures formed by the steam appear on the surface, and the whole pavement quickly falls to pieces. For the same reason asphalt should be laid only in dry weather.

Binder course.

The binder course consists of a layer about 1½ inches thick of broken stone cemented together with asphaltic paving cement and rolled in place while hot. This binds the wearing coat and the foundation together, and prevents the former from lifting from the latter or being pushed along in a wave. On account of the expense of maintaining the necessary appliances for mixing the stone and asphalt of the binder course, this course is sometimes omitted, and a thin course of material of the same composition as the wearing coat is laid instead, and is called a "cushion coat." This is usually from ½ to 1 inch thick, and being richer in cement adheres more firmly to the foundation than would the top coat.

Composition of wearing surface.

Asphaltum in a refined or pure state is valueless as a cementing medium, owing to its hardness, brittleness, and lack of cementitious properties; therefore it is necessary to add some substance which will impart to it the required plastic, adhesive, and tenacious qualities.

This substance must be one that will partially dissolve the asphaltene and form a chemical union by solution instead of a mechanical mixture. The duty which it has to perform is an important and peculiar one: if it is a perfect solvent of the constituents of the bitumen, the adhesive qualities will be destroyed; if it is an imperfect one, the asphaltum will retain its brittleness.

This prepared cement is termed the "matrix," and forms one of the two essential parts of asphalt cement pavements, the other part being the "aggregate." The success or failure of the pavement will depend upon the care exercised in the selection of these materials and the skill displayed in combining them and laying the pavement. Each has a distinct function to perform: the cementing material, or the matrix, preserves the coherency of the mass; the resisting material, or the aggregate, resists the wear of the traffic.

The aggregate consists of sand and stone dust or Portland cement. The sand must be clean and free from loam and vegetable impurities, and it should be composed of angular grains ranging from coarse to fine and having as small a proportion of voids as possible.

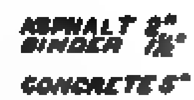
Mixing and spreading wearing surface.

In the making of the wearing surface, the asphaltic cement and the sand are separately heated. The proper amount of cement and sand are weighed out and simultaneously poured into a mechanical mixer consisting of two sets of interlocking revolving blades which thoroughly mix the materials, the process usually requiring 1 to 1½ minutes. When completed, sliding doors in the bottom of the mixer are opened, and the material drops out into carts or wagons which carry it to the street.

The mixed cement and sand is brought upon the street at a temperature of about 280° F. It is dumped upon the binder course and evenly spread over the surface with shovels and rakes, precautions being taken that no leaves, straw, pieces of paper, or other rubbish become mixed with the paving mixture. Care must be taken to secure an even distribution of the loose material to prevent the formation of depressions or elevations in the finished surface. The depth

a. Asphalt on Stone Blocks.

b. Asphalt on Macadam.



c. Heavy Traffic Pavement.

d. Light Traffic Pavement.

FIG. 198.—Type Sections of Asphalt Pavements.

of the mixture is regulated by chalk lines on the curb, by the length of the teeth of the rake, and sometimes by rods supported on feet of a length sufficient to bring the top of the rod to the level of the uncompacted asphalt mixture. The thickness after being rolled is usually about 2 inches.

The first compression is given by hand rollers and tamping

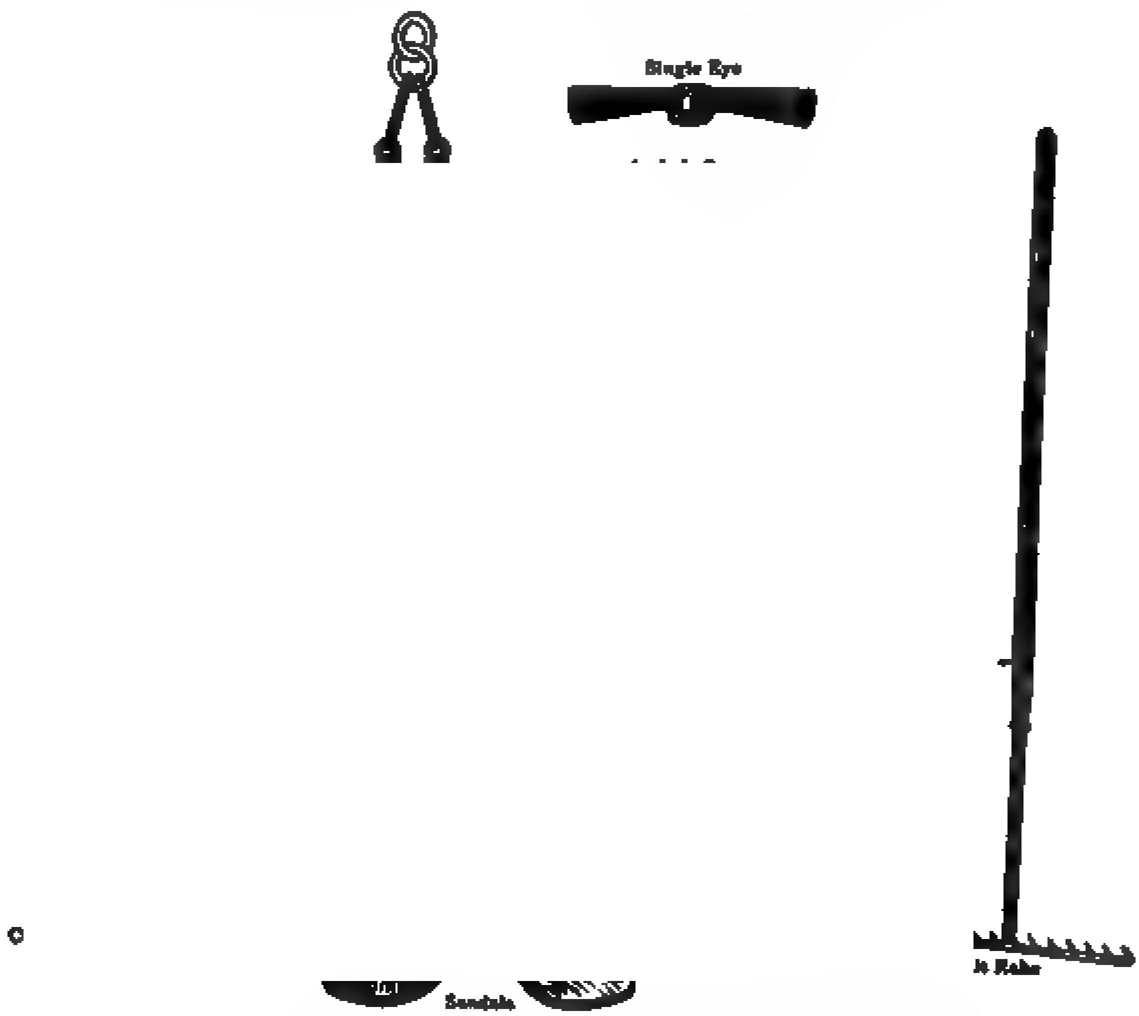


FIG. 199.—Tools and Appliances for Laying Asphalt Surface.

irons. The hand roller has a fire-pot inside for heating it, and the tamping irons, which are used around manhole covers and curbs, etc., where the roller cannot conveniently be used, are heated in a fire in an iron basket, which is moved from place to place on wheels.

After this first compression, men with tamping and smoothing irons, finish the gutters, joints, and all angles which cannot be reached with the heavier rollers.

The first compression having been given, some natural hydraulic cement or any impalpable mineral matter is dusted over the surface to give it a more pleasing color and to prevent adhesion to the roller; and then the surface is rolled with a special pattern of steam-roller, until the roller leaves no mark. This rolling should closely follow the spreading of the material, so that it shall not have time to cool before the final compression is obtained. The state of the weather is also an element to be considered, for if a strong wind be blowing, the

Fig. 200.—Hand Asphalt Roller with Fire-pot.

material, spread over a broad surface only 2 to 3 inches thick, will cool much more rapidly than on a calm day, even if the temperature is considerably lower.

When the rolling is completed, the pavement may be thrown open, as traffic, if not too heavy, is of advantage to a newly-laid asphalt pavement, since the pressure of the wheels aid in consolidating the wearing coat and in closing the surface.

The top of the binding course should be perfectly dry when the wearing surface is laid, to prevent its being separated from the course below by the formation of steam. Asphalt

FIG. 201.—Street Kettle for Asphalt.

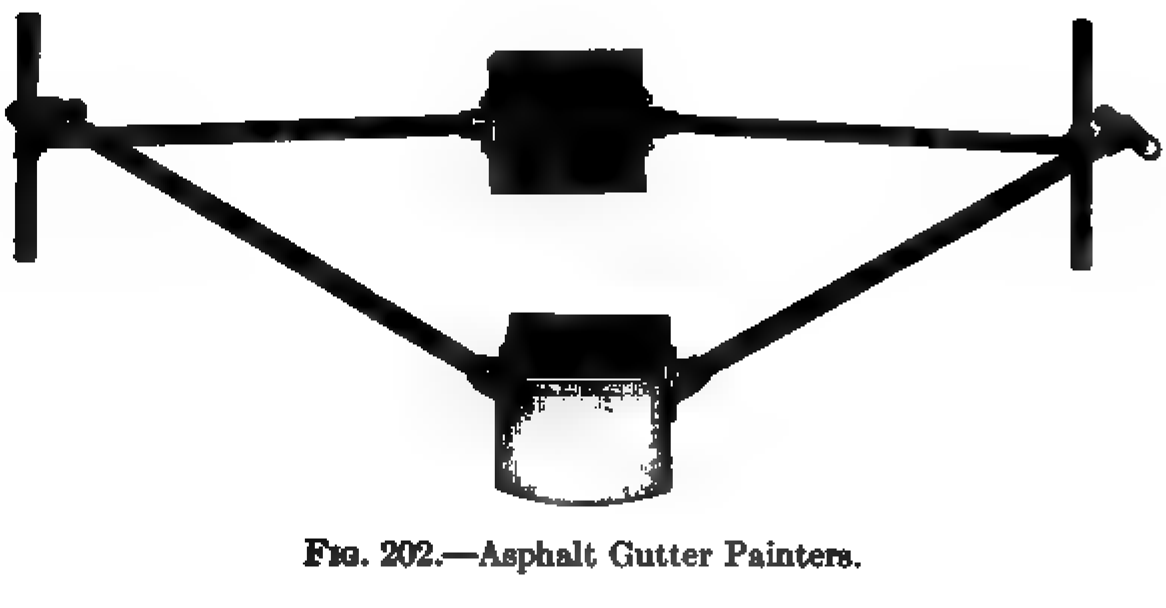


FIG. 202.—Asphalt Gutter Painters.

should not be laid in cold weather, as the paving mixture may become chilled between the mixing plant and the street, and particularly when it comes in contact with the cold foundation.

The chief points requiring skill in the spreading of the asphalt surface are:

1. To avoid inequalities of the surface, especially depressions which prevent the rapid removal of storm water.

a. Gutter in which Water Flows.

FIG. 203.—Action of Water on Gutters of Street Paved with Asphalt.

2. To secure thorough consolidation of the gutters, which otherwise rot rapidly.
3. To give it a thorough rolling; the asphalt mixture cannot be fully compacted by simple pressure, but requires the kneading action of repeated passages of the roller.

Failures of asphalt pavements.

There have been frequent failures of asphalt pavements, which may have been due to any one, or more, of the following causes:

1. Unsuitable Materials:
   - Asphaltum which has been so changed by natural causes as to possess little or no cementing power.
   - Fluxing agents, such as those which are not solvents of asphaltene, and thus form a mechanical instead of a chemical union, or such as those which, for other causes, render the pavement brittle, in which condition it is easily broken up under the action of the traffic.

b. Gutter Carrying no Water.

FIG. 203.—Action of Water on Gutters of Street Paved with Asphalt.

   - Sand, either too coarse or too fine, or containing loam, vegetable matter, or clay.
   - Free oil in binder.

2. Improper Manipulation:
   - Too high heat in refining the crude asphaltum, which reduces or entirely destroys its cementing qualities.
   - Improper consistence: if the cement is too hard, the pavement will have a tendency to crack during cold weather;

and if too soft, if will push out of place and form waves under the traffic.

Insufficient quantity of cement. This varies with the character of the sand—a fine sand requires more cement than a coarse one, and the proportion of cement must be varied to suit the character of the sand to be used.

Inadequate mixing of ingredients, whereby the cement and the particles of sand are not brought into intimate contact.

Rich binder. If an excess of asphalt or coal-tar is used in the binder course, it is likely to work to the surface and then becoming absorbed by the wearing surface, cause it to disintegrate.

Chilling of the cement while being transported from the mixing plant to the street.

Separation of the cement and sand. If the distance from the plant to the street is long and there is any unusual delay, some of the asphaltic cement may work to the bottom of the load, and when the material is dumped there will be both rich and lean spots, both of which are equally objectionable.

Laying the paving composition on a damp or dirty foundation, prevention it from uniting firmly with the foundation.

Inadequate compression, thus allowing the admission of rain and other water falling upon the surface of the pavement, with its destroying effects.

3. Natural Causes:

All materials in nature are undergoing changes due to the action of the elements, and asphaltum is no exception.

Ordinary wear decreases the thickness, due to the loss of material by the abrasion of hoofs and wheels, but in the case of asphalt pavements this loss of material is very slight.

Natural decay. Under the action of heat and water all bitumens undergo a change, and when the maximum of hardness is attained, natural decay sets in, and under the combined action of the elements, the material gradually rots and disintegrates.

Weak or insufficient foundation will, by unequal settlement, cause cracks and depressions in the asphalt surface which, under traffic, will speedily enlarge.

Leaky joints with curbs, crossings, etc., which permit the entrance of water under the asphaltic covering.

Porous foundation, which permits the ground-water to rise, by capillary action, to the underside of the wearing surface, where by freezing it may break the bond between the top layer and the base, and thus permit the wearing surface to be pushed out of place and broken.

Illuminating gas, escaping from leaky pipes under the

Fig. 204.—Destructive effects of Gas Leaks on Asphalt Pavement.
(From Judson's "City Roads and Pavements.")

pavement, is absorbed by the pavement, and causes the disintegration of the asphalt.

Cracks, due to the contraction of the wearing surface, after the pavement has lost part of its cementing power by several years use.

Shifting under traffic, due to too soft a wearing surface.

Bonfires which are sometimes built upon the asphalt pavement are likely to cause considerable damage.

Repairs.

The repairs necessary in the maintenance of asphalt pavements may be classified as those due to:

1. Settlement of the subgrade.
2. Disintegration of the pavement in spots.
3. Formation of waves.
4. Formation of cracks.
5. Disintegrating effect of water in the asphalt gutters, necessitating frequent "painting" with rich asphalt or bitumen.
6. Defects next to the street-car rails, crossing stones, manhole covers, etc.

Fig. 205.—Surface Heater for Repairing Asphalt Pavements.

Asphalt Block Pavement

Manufacture.

The manufacture of paving blocks from crushed stone and asphaltic cement was begun in San Francisco in 1869, but in consequence of imperfectly prepared materials and crude appliances, the blocks were weak and friable and the results were unsatisfactory. Improvements have been made since that time in both the processes and the machinery, resulting in the production of tougher and more durable blocks, which are now used extensively in various parts of the United States.

The blocks are composed of crushed stone and asphaltic cement in the proportions of 87 to 90 per cent of stone and 13 to 10 per cent of cement. The materials are heated to 300° F. and are mixed in a rotary mixer until all the faces of every particle of the crushed stone are perfectly coated with the mixture of asphaltic cement and limestone dust. The

product is then put in molds 12 inches long, 4 or 5 inches wide, and 3 or 4 inches deep, and subjected to a pressure of 2 to 2½ tons per square inch and then slowly cooled in water. The blocks weigh from 22½ to 24 pounds each, according to the specific gravity of the stone employed, and about twenty-six blocks are required per square yard.

The blocks are laid on the street in close contact, in the same manner as stone paving blocks, either with or without an artificial foundation, the foundation usually employed being gravel, or gravel and sand, or sand alone.

The advantages and defects of the sheet asphalt pavement are equally applicable to asphalt block pavements, but they have the special advantage over "sheet asphalt" in that they can be made at a factory located near the materials, whence they can be transported to the place where they are to be used, and laid by ordinary pavers without the aid of skilled labor; whereas sheet pavements require special machinery and skilled labor in each city where they are laid.

Compared with stone blocks they are much smoother and less noisy, and they form a practically impervious pavement, because under the action of the sun and traffic the asphalt cements the blocks together.

For narrow well-travelled streets they do not make a suitable pavement, but where the traffic is of such a character, as on residence streets, to warrant their use they make, when laid upon a concrete foundation, an excellent pavement, smooth, durable, and easily cleaned, healthy, and pleasant to the eye.

Coal-tar Pavements

In their earlier construction, the wearing surface of coal-tar pavements consisted essentially of small gravel, sand, and stone dust, cemented by a product of coal-tar. In the later pavements, a certain proportion of bitumen is mixed with the tar with beneficial results.

Wherever laid in the United States, coal-tar pavements, as a rule, have given little satisfaction, their failure being due to the presence of volatile oils in the tar, which on exposure to

atmospheric influence slowly oxidize and become inert, thus destroying the cementing qualities of the tar. If these oils are removed before the tar is used the resulting material is brittle, and soon crumples to pieces after being laid. Coal-tar is also very sensitive to heat: in summer it is soft, in winter brittle. On account of these defects, the use of coal-tar alone, as a cementing material for pavements, has been almost entirely abandoned.

Coal-tar and asphalt. To overcome the defects of coal-tar when used alone, the practice has arisen of mixing the gas tars with bitumen, and this has been successful in proportion to the amount of the bitumen used.

Advantages of coal-tar and asphalt pavement are:

1. Cheapness.

2. A surface more granular and less slippery than asphalt.

3. The binder binds the base and wearing surface firmly together and eliminates to a great extent the faults of weather cracks and wave surfaces.

4. Can be laid from curb to curb, as it will not "rot" in the gutters as does the asphalt.

5. Low cost; pavements constructed of carefully selected and combined materials and properly laid will cost but little, if any, more than the asphalt for maintenance.

Defects of coal-tar and asphalt pavement are:

1. The wearing surface consists of 75 per cent of coal-tar, which material can rarely be obtained of uniform quality.

2. The wearing surface, being only 1½ inches thick, requires renewal at frequent intervals.

3. The pavement is not so pleasing to the eye as asphalt in color.

4. The use of the bituminous base gives rise to many problems in the grade of the streets on which it is used, due to the fact that the base, the binder, and the wearing surface coalesce so as to form a solid mass. The wear on the surface is never quite uniform; and when the binder or base becomes exposed on the most travelled part of the street, the pavement near the gutter may be worn but slightly. To resurface properly, the remnants of the old surface must be removed,

and the new surface laid directly upon the binder. It is, however, impracticable to strip a coal-tar surface. It may be broken by the pick and bar, but it breaks as readily in the base or binder as at the original line of demarcation. In fact, there is no such line. The practice is to cut out what may be necessary near the curb and put a new surface on the roadway as it stands. The result is to raise the level of the roadway at every resurfacing, or, if the original level at the curb be maintained by the method of cutting out as stated, to increase the crown of the street; but as such pavements will not, as a rule, require resurfacing at more frequent intervals than every fifteen years, and as the surfacing should not raise the level more than one-half inch, the upward growth will not exceed $3\frac{1}{2}$ inches per century.

If the surface is tarred over every year with a brush and sprinkled with sand, the life is lengthened.

CHAPTER XVIII

CONCRETE PAVEMENTS

PORTLAND CEMENT forms in combination an artificial stone which increases in hardness and strength with age; it is displacing natural stone in many kinds of construction and has recently had much consideration as a paving material. Concrete has long been used for the foundation of pavements (see page 399) and in a few cities, principally in Philadelphia, alleys have been paved with concrete laid in the same manner as for sidewalks, but owing to its high cost, concrete has not met with the approval of leading paving authorities for the wearing surface of roadways. This principal objection may be said to have been met now that the enormous growth in its production has greatly decreased its cost, and its use for highway purposes will undoubtedly increase.

In recognition of the growing importance of concrete in road construction, the Committee on Concrete Review of the Association of American Portland Cement Manufacturers offered two prizes, one of $75 and one of $25, for articles on this subject, the medium selected for publication being *Good Roads Magazine.**

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* The first prize was awarded to Ernest McCullough, C.E., Chicago, and the second prize to Charles W. Ross, C.E., Street Commissioner of Newton, Mass., On the subject of the awards the Committee, whose members were George W. Tillson, E. L. Powers, and Percy H. Wilson, sent the following communication to Albert Moyer, of New York, Chairman of the Committee on Concrete Review:

"The Jury of Award appointed to judge the papers submitted through the *Good Roads Magazine*, met on March 19, 1909, and after carefully considering the merits of the papers presented, decided to award the first prize of $75 to paper No. 2099.

"Our reasons for doing this were: First, on account of the able discussion of the merits of a concrete roadway as compared with roadways built of other materials; and, second, owing to the comprehensive details

The advantages of concrete as a paving material, and the methods of its application as brought out in the first prize paper and summarized in this chapter, constitute all the available information on the subject, based on the experience of a practical road engineer. Mr. McCullough has endeavored to show that concrete offers a paving material containing an extremely large per cent of all the desirable qualities given in Baker's table of relative values (page 29) of the items forming an ideal pavement, and in almost the exact ratios.

Advantages of concrete.

In respect to first cost concrete is without a competitor, for the materials lie within easy reach of all who want paving material. Few districts are without stone good enough for the main body of the pavement and when sand is not to be had readily, crushed stone is good. The binding element, the cement, is within the reach of every village, town and city in the country at approximately two dollars per barrel, and a very small amount of this is required when proper methods are adopted to proportion the concrete. There are no patents to conflict, so that every man who can mix concrete may become his own paving contractor. The principal question in the selection of paving materials is this one of first cost, and the desire so many have to see all their money spent near home, which has always been a source of trouble, will not be so hard when concrete is more generally adopted. It is the one material that is low in first cost and yet economical in the end.

First cost.

The presence to-day of the magnificent roadways of old Rome gives evidence of the low cost from the maintenance standpoint of a properly constructed concrete pavement. All that is necessary is to do the work right. The setting of concrete is a process of crystallization, that proceeds best when just enough moisture

Cost of maintenance.

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of construction; third, that, in our opinion, when constructed it would make the best roadway of those discussed in the papers.

"The second prize of $25 we awarded to paper No. 2101. First, because of the comprehensive description of a concrete roadway which can be used for country work, and, second, because of the logical manner in which the whole subject has been treated."

FIG. 206.—Boulevard Road, West Newton, Mass. Before Treatment.
(Courtesy of Chas. W. Ross, Street Commissioner.)

can reach the concrete. This process continues for years. Concrete roadbeds being embedded in the earth, where they will be continually kept moist by the water absorbed from the soil, and wet almost daily by rain or snow from above, must grow stronger with age and it then becomes merely a question of doing the work properly at first. This means careful selection of the cement, the sand and the principal aggregate, the mixing and the depositing, and the prevention of jarring until the material shows evidence of having set enough to withstand ordinary traffic.

The manufacture of Portland cement has reached so perfect a plane that little or no trouble can be experienced in the cement. More trouble arises from improper selection of sand and stone and poor mixing than from the cement used, for to-day American Portland cement is a standard article produced by thousands of mills all working to turn out a product that will pass tests that are standard over the whole world. Therefore it can be truthfully said that a properly constructed concrete roadway is the lowest in cost of all roadways from the standpoint of maintenance and is practically everlasting. The elements do not affect it. It is impervious to acids, gases, oils and all the other things that attack other paving materials and it requires no coating with costly materials to protect it.

Ease of traction.

Tractive resistance can be shown best by comparison with other materials. An estimate made in Indiana years ago gave the following costs for horse-power per ton mile to haul goods over various pavements:

Asphalt	2.7 cts.
Block stone pavement (average)	5.3 "
Macadam in good order	8.0 "
Gravel road	8.8 "
Earth road, hard and dry	18.0 "
Macadam with ruts	26.0 "
Wet sand	32.0 "
Earth road with ruts and mud	39.0 "
Dry sand	64.0 "

FIG. 207.—Boulevard Road, West Newton, Mass. Mixing and Spreading Concrete.
(Courtesy of Chas. W. Ross, Street Commissioner.)

No mention is made of wood or of brick but experiments made in many places indicate that these materials are practically on a par with asphalt. On this point the following table gives the force required to draw one ton on *

Material.	
Iron	10 lbs.
Asphalt	15 "
Wood	21 "
Best stone blocks	33 "
Inferior stone blocks	50 "
Average cobble stone	90 "
Macadam	100 "
Earth	200 "

Considering that a concrete roadway may be made perfectly smooth if desired, or can be roughened as much as the contractor thinks is right, it is hard to fix a value that will represent ease of traction. It may be made fully as smooth as iron if desired, and thus present exactly the same resistance value, or it may be cut into block form to resemble a first-class Belgian block pavement and thus have a value equal to that set for the best stone blocks. Expressing it in cost per ton-mile it may range from one cent to six cents. There is never any occasion for it to be higher as the material is more easily repaired than any other and a good surface may always be maintained.

Foothold.

Good foothold depends entirely upon surface, and the top surface is capable of so many degrees of roughness that the pavement, properly constructed and finished will never offer a poor foothold for horses and will always have a good surface for automobiles. Should it become too hard and smooth, it is a very easy and inexpensive matter to roughen the surface. Any desired finish can be given it and thus all objections on the ground of lack of good foothold can be removed.

* Captain (now General) Francis V. Greene, in *Harper's Weekly*, of August 10, 1889.

FIG 208.—Boulevard Road, West Newton, Mass. After Treatment.
(*Courtesy of Chas. W. Ross, Street Commissioner.*)

Concrete is not so noisy as other pavements, in spite of its being a hard pavement,—a fact borne out by residents on streets paved with concrete. The reason is easy to find. Like asphalt, it is smooth so that wagons going over the surface make a minimum of noise. It has, however, the advantage that the pavement and foundation are monolithic. When bricks or paving blocks are used there must be a concrete base. It often happens that an arching action, caused by the effect of the temperature in the pavement, makes it rise above the foundation base in places and producing a rumbling noise that is very distressing at times. Therefore, expansion joints are placed at frequent intervals in the pavements laid on a concrete base. The concrete pavement consisting only of the concrete base used for other pavements and a finish, there can be no separation to cause a rumbling, and outside of this, noise is caused only by the condition of the surface which is entirely within the control of the men putting down the roadway.

Noiselessness.

Ease of cleaning and healthfulness should be considered together. A concrete pavement can be washed with a hose at any time, and as it contains no joints, no dirt can collect on the surface. Its healthfulness, therefore, cannot be questioned. It yields no detritus of itself and therefore the mud and dust that may appear on the surface must be brought on by wagon wheels from other streets, or is thrown on in other ways. In itself a concrete pavement is absolutely free from mud and dust.

Cleanliness and healthfulness.

Concrete is one of the poorest conductors of heat known and being light colored is a reflector of heat rather than an absorber. It has been noticed that cement sidewalks after nightfall are much cooler to the touch than asphalt paved roadways and early in the mornings the cement sidewalks are cool to the hand, while the roadway paved with asphalt is still warm from the heat absorbed the day before. A pavement that is highest in ease of traction; offers perfect foothold for animals and a perfect

Acceptability.

hold for fast traveling automobiles; that is always clean; practically noiseless; free from dust and dirt; non-absorbent of heat; must be comfortable to use in a degree denied other pavements.

Construction. The preparation of the surface of the earth for the laying of the pavement is no different from the preparation required for pavements of other materials. The cross-section must be crowned, the crown depending upon the grade of the road or street as well as upon the material. For concrete roadways the crown recommended is that used for stone.

The ground should be formed carefully to the contour of the finished surface and at a distance below this surface equal to the amount required by the specifications. It should be carefully excavated and all soft spots should be dug out and refilled with good, clean, hard material, after which it should be alternately sprinkled and rolled until a wagon with two-inch tires loaded with two tons of material can be drawn over it without making an appreciable indentation.

The foregoing requirements are for a clay or heavy soil, but when the material is sandy or gravelly, of course such hardness in the rolled surface cannot be obtained. The distance of the earth surface below the finished surface of the roadway likewise depends upon the character of the soil over which the road will go. If it is sandy or gravelly, then the concrete can rest directly upon it. If it is clay or heavy soil, there should be at least three inches of sand, gravel, broken stone, or hard cinders between the earth and the concrete. This cushion coat is placed to minimize the danger from frost.

All fills in the sub-base should be made in thin layers well moistened and rolled. For a monolithic pavement, such as concrete, this perfect preparation of the sub-base is of great importance and extra care should be used.

A half-inch board should be set on edge on a line on each side of the street about three or four feet away from the edge of the roadway; about where the edge of the gutter would be if the gutter were constructed. This board should

be slightly beveled and be coated heavily with oil on either side. When the concrete is deposited this board is lifted and the space should be poured with a preparation of asphalt made for the purpose. This joint on each side is a longitudinal expansion joint and there are many prepared fillers for expansion joints on the market. A good one can be made of asphalt mixed with coal tar from which has been removed, by boiling, all moisture, leaving the pitch. Coal tar alone may be used and is frequently used for this purpose.

An expansion joint, to be such, must not be allowed to fill with dirt or sand, so the plastic filling is a necessity. Sheets of cork, tar and sawdust, tar and cork dust, as well as strips of tarred paper heavily coated with cork, have all been used with success. At intervals of about fifty feet there should be similar expansion joints laid across the pavement. Although there has been some discussion over the necessity for such joints in concrete pavements, there are many such pavements in use and so far none have been constructed without expansion joints.

No work should be done when the temperature, either night or day, falls below 35° Fahr.

Hassam pavement.

One form of concrete pavement is patented under the name of the Hassam pavement, after the inventor. After the roadway has been thoroughly compacted, it is covered with broken stone to a depth of practically the pavement thickness in the same manner as that generally specified for a macadam pavement, and the stones are so graded that the voids are reduced to a minimum. After the stone has been rolled until it practically ceases to move under the weight of the roller, a thin grout composed of Portland cement, one part and sand two parts, is poured on the stone until the voids are filled and the grout rises to the surface. The rolling or tamping continues during the process of grouting. Then a very thin layer of pea gravel is placed all over the surface and rolled until the grout flushes up through it.

Another form of concrete pavement, not patented, is to mix

stone, sand and cement together precisely as in mixing concrete, but no water is added. This dry material, really a macadam, is then spread over the surface and treated as macadam is treated. When sprinkled and rolled, of course it is converted into regular concrete, but as it has considerable solidity before wetting, the roadway is very solid. It has been used greatly as ballast for surfacing tracks of electric roads and permits of good work being done in this way. The track can be perfectly aligned and adjusted and then the concrete wetted and permitted to set afterwards.

The best way to make a concrete roadway, however, is to make it in the regular way by depositing layers of concrete until the desired thickness is obtained, and then finish the surface according to what is considered best for that particular locality.

Materials. Concrete is composed of sand and cement mixed together to form a paste and with some aggregate that will combine with this paste to make a good stone. The best aggregate is, of course, stone.

The following specifications for materials for Portland cement sidewalks, adopted by the National Association of Cement Users, January 24, 1908, serve to show what is considered good practice in selecting the materials:

"Sand shall pass a No. 4 screen and be free from foreign matter, excepting loam or clay, which will be permitted if the quantity does not exceed five per cent, and when these ingredients do not occur as a coating on the sand grains.

"Not more than 40 per cent shall be retained on a No. 10 sieve, or

35 per cent pass a No. 10 and be retained on a No. 20 sieve,
20 per cent pass a No. 20 and be retained on a No. 30 sieve,
30 per cent pass a No. 10 and be retained on a No. 40 sieve,
40 per cent pass a No. 40 and be retained on a No. 50 sieve.

"Not more than 20 per cent shall pass a No. 50 sieve, or

70 per cent pass a No. 10 and be retained on a No. 40 sieve,
70 per cent pass a No. 20 and be retained on a No. 50 sieve.

"Stone shall be crushed from clean, sound, hard, durable

rock, be screened dry through a ¾-inch mesh, and be retained on a ¼-inch mesh.

"Screenings from the crushed stone specified above, which shall meet the requirements for sand, may be substituted for sand if so approved.

"Gravel shall be clean, hard, and vary in sizes from that retained on a ¼-inch mesh to that passed by a ¾-inch mesh.

"Unscreened gravel shall be clean, hard and contain no particles larger than ¾-inch. The proportions of fine and coarse particles must be determined and corrected to agree with the requirements for concrete.

"Water shall be reasonably clean, free from oil, sulphuric acid and strong alkalies."

In the foregoing requirements those for sand are first-class, and nothing can be added. In regard to the use of stone screenings in place of sand, it is well to note that all dust must be screened out and the screenings used should comply with the specifications for sand as to size of grains. The dust is apt to ball up badly and prevent a good, thorough mixing. It also requires more water.

The unscreened gravel referred to means ordinary gravel as this term in understood by the average man. As an excess of sand is weakening to concrete care should be taken to see that the proportions are about right when using such ready mixed gravel. It is always best to screen gravel and remix in proper proportions.

The caution about using clean water is a good one. It is a common practice for sidewalk men to use water from gutters and drains on their work and then blame the cement for failures.

When working in sections of the country where there is considerable alkali the water should be tested and should never be used if it contains alkali. The gravel should also be tested as well as the sand. If it is impossible to obtain other material within a reasonable cost, samples of the water, sand and gravel should be taken to a competent chemist for analysis in order to see whether the alkali contained is likely to be harmful to the concrete, as some of the salts known commonly as "alkali" are not harmful.

The stone used for concrete roadways can be slightly larger than specified, but should not exceed one and one-quarter inches in the largest dimension and should be as nearly cubical in shape as possible. Rounded gravel packs better than broken stone and occasionally broken stone comes from a formation that is rather brittle and the crusher causes small cracks that extend throughout the stone and are apt to be a source of weakness.

In building concrete roadways, however, one is not compelled to use stone only. Concrete can be made with stone, broken brick, burnt clay ballast, slag, clinkers, chats, and, in fact, any good firm material that is able to stand exposure to the weather without breaking down, that will not melt or be too readily attacked by moisture or acids. The bed of the pavement can be made of good concrete materials and the topping or surfacing of good sand.

The standard sidewalk specifications of the National Association of Cement Users further say:

"The concrete for the base shall be so proportioned that the cement shall overfill the voids in the sand by at least five per cent and the mortar shall overfill the voids in the stone or gravel by at least ten per cent. The proportions shall not exceed one part of cement to eight parts of the other materials. When the voids are not determined the concrete shall have the proportions of one part of cement, three parts sand or screenings and five parts stone or gravel. A sack of cement (94 pounds) shall be considered to have a volume of one cubic foot.

"To determine voids, fill a vessel with sand and let net weight of sand equal B. Fill same vessel with water and let net weight of water equal A.

$$\text{Per cent of voids} = 100(2.65A - B)/2.65A$$

"This formula may also be used in determining voids in crushed stone and screenings by substituting for 2.65 the specific gravity of the stone."

The following is a more simple method for determining voids in coarse aggregates: "Fill a vessel with the aggregate and let net weight equal B. Add water slowly until it

just appears on the surface and weigh. Let net weight equal A. Fill the same vessel with water and let net weight equal C.

$$\text{Per cent of voids} = 100(A-B)/C$$

"Use a vessel of not less than one-half cu.ft. capacity. The larger the vessel the more accurate the result."

Method of work.

These specifications are very good, but the men who do the work are generally opposed to all the weighing, and the formulas, simple as the calculations are. The following method is recommended: Make a box two feet wide, five feet long and one foot deep of two-inch tongue and grooved plank, white leaded in the seams so it will not leak. Fill this box level with the larger aggregate. Then pour into it slowly and carefully water from cans of definite size. When the box is full the amount of water in cubic feet represents the per cent of voids in the stone, because the box contains exactly ten cubic feet. Empty the box and spread the stone on a platform. Measure out sand that will represent the voids found in the stone and mix the sand and stone together, then fill the box with the mixture. After this is leveled off, pour in water, carefully measuring it as it goes in, and the amount of water will represent the voids in both stone and sand. If this does not exceed ten per cent, it will represent the amount of cement required, but if it exceeds ten per cent, then some fine sand should be used to fill part of the voids. Density is wanted and the most dense concrete is obtained when the materials are graded in size.

Proportioning materials.

It does not do to go to too much expense in grading the concrete materials, but some expense should be gone to in this regard for the quality of the material obtained will pay for the extra work. The most commonsense method of ascertaining the right proportions is that given by Wm. B. Fuller:* Use a piece of iron pipe about ten inches in diameter

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* Taylor and Thompson, "Concrete."

and weigh it carefully. Mix some concrete in the proportions intended for use on the work and tamp it into this pipe and note the height to which the pipe is filled. Weigh the pipe with its contents and throw the concrete away before it sets. Now make another batch with the same amounts of materials, but in different proportions. Weigh this like the first one. Make a number of batches in which the cement shall be one-eighth of the mass, but in which the sand and stone proportions will be altered. That batch in which the clyinder is filled the least, and which weighs the most per unit of volume is the most dense concrete. This method is sensible, because the materials at hand must be used and no expense be incurred in screening and separating in order to make exact proportions. By proportioning by Mr. Fuller's method, a 1:2.5:5.5 mixture may, for example, be used instead of a 1:3:5 mixture. The sand may be coarse or be in fact a very fine gravel containing considerable sand; in which case a 1:3.25:4.75 mixture might be used.

Mixing.

The concrete should be mixed in a machine, as this gives superior concrete at a much less cost than hand mixing. With batch mixers, each batch is certain to contain the exact proportions called for and to receive the right amount of turning. There are, however, a number of constant delivery, or continuous, mixers that can be safely used, provided a constant watch is kept on the cement feed. This is the most important and the one that gives the most trouble.

Hand mixture for concrete roadways can be done more cheaply than the hand-mixing usually called for in building work. Two steel platforms, twelve feet long and six feet wide, are used, which are turned up at each end and have a heavy plank on each side, so they resemble in appearance river scows, having a depth of one foot. Over one end is spread the stone in the number of inches that corresponds to the proportion required in the mixture. Over the stone is spread the sand in its proportion. Over the sand is spread the cement. Some men spread the sand first and put the stone on top, then cover with cement. The reason is that they say some of the sand will sink into the voids in the stone and

thus more sand is used than should be. If the sand is put down first the stone will not be lost in it and as the cement is measured in bags anyhow that if some cement goes down into the voids it does not matter. The difference is not worth wrangling over.

Say, for example, the mixture is 1:3:5. A layer five inches deep of stone will be spread over the platform and upon that will be spread three inches of sand. One inch of cement will cover it evenly. The measuring is not done by guess, but by boxes. A frame of wood five inches high and, say, five feet square, is placed on the platform and this is filled even to the top. Then another box, the same size (without a bottom), is placed on it, but this frame has a height of only three inches instead of five. This is filled with sand, after which the frames are lifted by handles at the corners and the stone and sand spread. The cement is determined by a certain number of bags to the batch and this number of bags is placed over the sand.

When this is done the frames are taken to the next platform alongside the first and the same process followed. On the first platform are standing men with rubber boots and having long-handled hoes, such as plasterers use. For a platform six feet wide five men will be necessary. As soon as the material has been smoothed, these men commence with their hoes to pull it over about a foot at a time. They take a slice about a foot wide off the front edge and pull it ahead about two feet, then take another foot in the same manner until the whole mass has been gone over. Then they start at the front and pull it again in the same way. Three pullings and it is at the far end of the platform when they immediately begin to pull it back. This time, however, two men start in to sprinkle it with rose nozzles and the three times the mass is turned it is turned wet. This makes a total of three turnings dry and three turnings wet. By this time the other platform is ready for their attention and the men go there while the wheelbarrow loaders shovel the mixed concrete into wheelbarrows from one end of the platform while another batch is being prepared for the men with

the hoes, at the far end. Sometimes it is possible to arrange these mixing platforms so the concrete can be thrown directly into place without using wheelbarrows. However, it does not always pay to substitute shoveling and long throwing for wheelbarrow work.

The usual methods of hand mixing can just as well be followed, of course, but the method described is the lowest in cost and produces excellent results. The concrete should be very quaky and in fact should flow readily, but should not run like thin milk. It should be like a sticky heavy cream.

The concrete must be solid, not porous. Tamping or rolling should be insisted upon.

Topping and finishing.

The topping should be not less than one inch thick. Sometimes it is two inches thick, but that is extravagant. It should be put in place within thirty minutes after the base has been placed if possible, but under no circumstances should it go on after an hour. First spread a thin mortar coat of nearly pure cement mortar over the base to the depth of about an eighth of an inch and then put on the topping.

The topping should consist of pebbles about one-quarter of an inch in size. The voids should be determined and one-half the voids filled with material about an eighth of an inch in size. The remainder of the voids should be filled with clean, coarse sand. This mixture composes one-half the topping, the other half being cement. Some men use one and one-half parts of this mixture to one part of cement. Trial had best be made by the party doing the work, for so much depends upon the coarseness of the materials. Fine sand is usually round and requires more cement.

This topping is floated with wood floats, as steel floats produce too smooth a surface. It is cut through at the expansion joints and lined off into blocks the size and shape of stone paving blocks. The cuts over the expansion joints in the base are filled with the regular expansion joint composition.

Sometimes the surface is not floated but the topping is put on and tamped somewhat, after which it is swept with

a very coarse broom. Occasionally we see the surfaces treated with acid to eat away the cement before it is fully set, so the stones will appear and make the surface rough for foothold. Sometimes after the topping is on and before it is set, a covering of pea gravel is put on and rolled in with a lawn roller.

When the surface is finished, there should be a covering of sand or straw put over it and this covering should be kept wet for a week, after which it is taken off and the street surface exposed for three days longer, when it is ready to be thrown open to traffic. Sometimes no covering is put on and sometimes a covering or burlap is used. Each method has its advocates and each has been used with success.

The street surface should be wet every day, and if possible, kept pretty wet for two or three weeks after completion. When a very fine surface is placed on the road and it is blocked off to imitate paving blocks the roadway is generally thrown open for travel within eight or ten days. Sometimes one week is considered long enough. When a rough surface is made it is usual to make traffic wait longer.

The cost of such roadways is less than the cost of any other pavement used, for it consists of just about the thickness of concrete used for such roads. It costs just a little more than the bare concrete used for the foundations of pavements of wood, asphalt, stone or brick, and the cost of the topping is much less than the cost of these wearing surfaces.

Figures on cost vary greatly in different sections of the country, and the work done so far on concrete roadways in the United States has been generally done in good-sized cities by experienced contractors with trained men. Not much work of this kind has been done in small towns by contractors and until more of it has been done it is hardly right to publish cost data on the work.

In spite of the many advantages of cement roads brought out by the writers of these papers the limited experience of engineers in this form of road has shown that its rigid surface does not for long withstand the constant blow of horses'

Fig. 209.—Preparing the Surface.

Fig. 210.—The Finished Road Surface.
Experimental Concrete Cube Roadway.

hoofs and the action of the iron tire, while its rigidity also makes it injurious to horses.

Road surface of Concrete cubes.

Figs. 209 and 210 illustrate an experimental road surfacing of two-inch concrete cubes, built by the Highway Commission of New York State.*

Concrete block trackway.

A trackway constructed of concrete blocks is described and illustrated in Chapter XXI.

CONCRETE FOUNDATIONS

The best specification is the one adopted by the National Cement Users Association at its meeting in Cleveland in January, 1909, as follows:

SPECIFICATIONS FOR PROPORTIONING INGREDIENTS FOR PORTLAND CEMENT CONCRETE FOUNDATION FOR STREET PAVEMENTS.

FINE AGGREGATE shall consist of sand, crushed stone, gravel, or slag varying in size, passing when dry through a screen with openings ¼-in. in diameter; shall be of siliceous material, clean, coarse, free from vegetable loam or deleterious matter and not more than 6% shall pass a screen having 100 meshes per lin. in.

COARSE AGGREGATE shall consist of crushed stone, gravel, brick or slag which is retained on a screen having openings ¼-in. in diameter and pass through a screen having openings 3 in. in diameter; shall be clean, hard, durable and free from all deleterious materials.

MORTAR shall be made with fine aggregate as above specified, mixed with such proportions of cement as will over-fill the voids in the fine aggregate by at least 5% of such voids.

CONCRETE shall be made of coarse aggregate mixed with such proportion of mortar made as above specified in sufficient quantity to over-fill the voids in the coarse aggregate by at least 10%.

SURFACE.—In the case of brick or other form of block pavements, the surface of the concrete shall be as smooth as practicable. In the case of asphalt or bitulithic or other sheet pavement, the foundation shall be finished as rough as practicable in order that the plastic surface will as thoroughly

* *Engineering News*, March 3, 1910.

as practicable unite with the concrete foundation and prevent slipping or separation between the concrete and the wearing surface.

In all cases the general contour of the surface of the concrete shall be as closely as practicable parallel to and the requisite depth below the surface of the completed pavement in accordance with the grades established, and the directions of the city engineer.

If any portion of the concrete when tested by a template or a straight-edge 6 ft. in length shall show a surface more than ½ in. above or ½ in. below the grade established by the city engineer, then the high places in such concrete shall be picked or otherwise brought down to the proper grade and the low places shall be filled to the proper grade with fine concrete.

Test for Voids.—To determine the voids in the "coarse aggregate" or "fine aggregate," prepare a vessel, the cubical contents of which is exactly 1 cu. ft. (1728 cu. ins.), being smaller at the top than at the bottom. Fill the vessel with the aggregate thoroughly dried "coarse" or "fine" as the case may be, which is to be used. Thoroughly shake or jar the vessel containing the aggregate until it is compacted as thoroughly as possible and the vessel is level full. Then ascertain the net weight of the fine aggregate in the vessel, deduct this weight from 166 (the weight of a 1 foot cube of mineral of which the fine aggregate is composed) divide the difference thus obtained by 166. The result is the percentage of voids.

The advantage of this specification is that if either the fine or the coarse aggregate furnished is of uniform size, the contractor will be required to use enough cement to fill the then large proportion of voids in the fine aggregate and enough mortar to fill the then large percentage of voids in the coarse aggregate. On the other hand, if materials are available which will produce a smaller percentage of voids in either the fine aggregate or the coarse aggregate, the contractor can figure his proposal accordingly and the city get the benefit of the lower cost of construction.

CHAPTER XIX

THE CLEANING AND SANITATION OF CITY STREETS *

STREET CLEANING, considered as a problem in sanitation calling for engineering skill, is of comparatively recent development, both in Europe and America, and was only rendered possible by first providing some manner of hard surface to work upon. Rome had its "*tribuni verum intentium*" at an early date—officials who were charged with the care and cleaning of the streets, markets, temples, baths, and other public places. Ordinances were framed, and more or less severely enforced, forbidding the throwing of any manner of filth into the river or into the streets of Rome.

Early history of street cleaning.

For some centuries after Paris was paved every citizen was compelled to repair the street before his house and to clean it at his own expense, in accordance with an edict of Philip the Bold, issued in 1285. This law was practically unobserved, however, and in the fourteenth century the streets of Paris are described as being in a horrible condition. Later laws made street cleaning compulsory, for nobles as well as for the common citizen, and in 1501 a company was formed for cleaning streets by contract with individuals. Street cleaning at public expense, in Paris, was inaugurated in 1609, and the sum of 70,000 *livres* was appropriated for this purpose from the public fund. In 1704 the city collected 300,000 *livres* for cleaning streets and maintaining lamps.

A pig figures prominently in the first Parisian ordinances forbidding the deliberate dirtying of the streets. The young King Philip, son of Louis "the Fat," was killed in 1131, as the

* Condensed partly from Beckman's "History of Inventions and Discoveries" (1846) and partly from "Modern Methods of Street Cleaning" (1909), by George A. Soper, Ph.D., M. Am. Soc. C.E.

(*From Soper's "Modern Methods of Street Cleaning"*)

FIG. 211.—London.—Motor Water Wagons used for Watering Streets Preliminary to Flushing.

result of a fall from his horse brought about by a pig in the streets. As a consequence of this accident an order was issued forbidding swine running loose on the streets of the city; but this order was bitterly opposed by the monks of the Abbey of St. Anthony, who resented this affront to the charges of their patron saint, and demanded liberty for the swine to go where they pleased. After some time spent in controversy, the pigs belonging to this abbey were granted a special dispensation and permitted to wallow at will, provided that they had bells attached to their necks.

Up to the fourteenth century, in Paris, and as late as 1750 in Edinburgh, citizens were permitted to throw from their windows into the streets before the house, any manner of slops, provided that they called out three times before doing so. This privilege, so inconvenient to the passer-by, was strictly forbidden in Paris in 1395, and from this time may be dated the first introduction into that city of sanitary conveniences. It is interesting to note that when Columbus sailed for the Indies, the palace of King Ferdinand of Spain was destitute of any conveniences of this nature.

In Germany the cleaning of streets was at first considered as a most dishonorable employment, which is some places was assigned to the Jews and to the servants of the public executioner. Up to the beginning of the seventeenth century the streets of Berlin were never swept, and pigs ran at large throughout the city. In 1624 the Elector desired the council to have the streets cleaned, but the council replied that it was impossible, as the citizens were busy on their farms. The dirt in the public market place accumulated to such an extent that in 1671 a law was passed compelling every countryman to take out of the city one load of dirt every time he came to market. Pig-sties in the streets were common until 1681, when an order was issued forbidding the feeding of swine within the city limits. Large puddles of filth were, however, allowed to collect, even before the doors of the best houses, and in the summer these puddles emitted a horrible stench. Mr. Beckman remarks of this city that, "If bronze and marble could smell, Blucher and Bulow, Schwerin and Liethen, and

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 212.—The Center of London on a Holiday

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 213.—London.—Orderly Bin and Hand-carts used in Street Work at Entrance to London Bridge.

duck-winged angels and two-headed eagles unnumerable, would be found on their pedestals, holding their noses instead of grasping their swords."

These filthy labyrinths which for centuries passed for highways and byways in foreign cities have given way to broad, handsome streets, and congested districts which thirty years ago were a reproach to civilization, have been entirely eliminated. In place of over-concentration of population within the limits of military fortifications, the great continental cities now cover large, roomy areas in which the needs of public health and welfare are provided for as nowhere else in the world.

The sanitary regeneration which European cities have experienced within the last half century has had no counterpart in America, where there has been no necessity for such revolutionary changes. American cities were all small when the world began to learn that efficient sanitation was an indispensable feature of every municipality. There was never such overcrowding, or such slums to clean, no such foci of filth to eliminate in the United States as existed abroad fifty years ago. In 1860 there were only sixteen cities in the United States with a population of 50,000 or more, as against one hundred and forty-eight in Europe.

Municipal growth in America.

The significant feature of municipal growth in America as compared with municipal growth in Europe has been less the expansion of cities already large than the great number of small cities which have sprung into existence. Hundreds of these cities have passed, and are still passing, rapidly through periods of infancy, youth, and middle age, toward a maturity which foreign cities had reached half a century ago; and their sanitation takes place as they grow.

That branch of scavenging which has to do with the question of street cleaning is not at first troublesome to the young American city. The streets are merely highways which run from one town to another and the houses which are built upon these highways are few and far between.

In course of time, as the population increases, the main

highway is paralleled and intersected by cross roads; these again are crossed and recrossed to satisfy the growing requirements of the place. Capacious gutters make their appearance on one or both sides of the streets, but, except for an occasional drain to some brook or creek, a final disposition of surface water is not provided for.

The first important public sanitary improvement to be made in the village is a public water-supply. The subject of street paving is then considered and some macadam is laid down. Means are sometimes provided in summer to keep down the dust, but the dirt which falls upon the pavement is removed only by wind, rain, and other natural agencies.

A sewage system is installed later in the town's growth, and the houses are gradually built closer and closer to one another until they stand in immediate contact. More attention is given to the pavement of the streets. Macadam is laid and sometimes brick; stone and asphalt come later. The ditches or gutters at the sides of the streets are eliminated and the storm water is collected from the well-graded streets through catch-basins into the sewers, along with house sewage.

The streets are not yet systematically cleaned. Dirt is often allowed to collect until the pavement is hidden from sight. Garbage and ashes are generally removed at public expense by contract. Sometimes the wastes are separated into two parts by the householders so that the refuse of the kitchens may be collected separately from the ashes and other wastes, and sometimes all the wastes are collected in one receptacle.

The city has now reached its period of adolescence—often one of high mortality due to the absence of proper sanitary control, and fraught with many dangers to the future of the place.

The period of maturity, that is, the period in which civic responsibility begins to express itself in such forms as the regulation of building construction, the control of traffic, the adoption of well-considered plans to insure public health and safety, is long delayed. The paving and cleaning of streets and the collection and disposition of city refuse are apt

to be the last matters to which the municipality gives itself proper concern.

In appearance and use the city street is in strong contrast with the rural highway, yet the street always remains simply a highway in the public regard. The houses are now close together, offering a solid masonry front as of one compact structure. The streets are paved across from house line to house line. The earth has disappeared beneath a casing of brick, mortar, and stone which is, or should be, impenetrable to water. The pavements should also be treated as though they were impenetrable to man, but in American cities they are being constantly broken through. They are torn up with little or no regard to the integrity and smoothness of the surface and with the sole idea of reaching the pipes and conduits beneath. The integrity of the surface has much to do with the cost of street cleaning.

As the city grows the height of buildings becomes greater and greater, making the streets relatively narrower, and interfering with free access of air and sunlight; it leads to overcrowding of the sidewalks and carriageways.

Uses of city streets.

The city uses its streets in a very different way than does the village. They connect every household and are not only arteries of travel, but are also places of amusement, health resorts, and business places for the people. The city man not only moves through the streets, he carries the dirt of the street into his home on his boots and clothing; he gets his food and air through the streets. Unfortunately, both food and air are often contaminated with the product of the ceaseless wear and tear of everything perishable in the city. Ground into impalpable powder and raised from the pavements by the wind this city dust hangs in the atmosphere and can plainly be seen in the air like a haze on a calm day. The quantity held constantly in suspension is so great that it affects the city's climate; it discolors both persons and their clothing; it turns marble and even granite, yellow and black, and can be found in masses which weigh pounds even at the tops of the highest buildings of New York.

(From Soper's Modern Methods of Street Cleaning.")

FIG. 214.—Westminster.—Orderly with Hand-cart.

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 215.—Westminster.—Sand Bin Filled for Use. Street Refuse is Shovelled into a Compartment at the Top.

Of all the many sources of street dirt, the greatest amount which becomes scattered over the street pavement originates from vehicular traffic. The ceaseless movement of vehicles, with their horses, contributes materially to the soiling of city streets. The transportation of sand, coal, hay, manure, and

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 216.—Westminster.—Street-crossing Sweeper near Houses of Parliament.

other loose material in poorly constructed and overfull wagons adds to the quantity of refuse in the streets, and in the average city the cleaning department itself adds materially to the work which it has to do. The carts are generally unsuitable for the conveyance of the kind and quantity of refuse they have to carry. In conse-

Sources of street dirt.

quence, dry refuse is blown from the carts and wet refuse drips from them.

Failure to collect house refuse with frequency and regularity causes it to be cast into the carriageways by the people and to fall upon the streets from overfull receptacles. It commonly happens that street-sweepers brush refuse into piles and leave it there for many hours without removing it. Traffic

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 217.—Paris.—Street Sprinkling by Hose.

and the elements pulverize and scatter the refuse under these circumstances and double the labor necessary to collect it.

In many places earth from country roads is dropped upon the pavements by the movements of vehicles. The opening of pavements to reach piping and other underground structures is an important source of street dirt. In some towns peddlers and push-cart merchants add materially to the dirtying of city streets. Finally, as sources of street dirt may be mentioned the improper storing of sand and other building

materials and the sanding of pavements by street-car companies and street-cleaning authorities.

As cities grow and become more and more congested, the need and difficulty of keeping the sidewalks and carriageways free from dust and litter increase; but in spite of praiseworthy efforts here and there, the streets of but few cities are kept in a satisfactorily clean condition. There are almost always large parts of even the cleanest cities which are very dirty.

Reasons for unclean streets.

One of the reasons for this unsatisfactory condition of city streets lies in the fact that the business of keeping a city clean is rarely understood by the public or by the officials in charge of the streets. In American cities of small size it is still customary to clean most of the streets not regularly and systematically, but spasmodically and ineffectively—often only when the conditions become so bad that public endurance will no longer tolerate them. The persons assigned to the labor are often recruited from the ranks of the unemployed and are likely to be either incompetent or unwilling to do a fair day's work. Sometimes men of advanced age, inmates of poorhouses and even convicts, are put upon the streets to clean them. Any kind of labor seems to some good enough, and it is small wonder that the results are so often unsatisfactory.

Aim of Sanitation.

The aim of sanitation is to get control of wastes as soon as possible after they are produced and maintain this control until they are permanently disposed of. It is both easier and cheaper to collect large particles of refuse and small particles when present in relatively large and compact masses, than to allow the refuse to be broken up and scattered before attempting to gain possession of it.

Coöperation required.

In order to facilitate the work of the street-cleaning department, and insure its success, coöperation is desirable between those city departments which are responsible for the paving of streets, the opening of pavements, the regulation of traffic, the storing of building materials, and the management of markets, as well as with

householders. Effective coöperation of this kind is rare in America, but in Europe all these matters, and more, are not uncommonly attended to by one central authority.

The city waste materials may be divided into three divisions:

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 218.—Bertin—Electrically-driven Machine for Cleaning Streets.—The Highest Development which Street-cleaning Machines have thus far Attained.

(1) sewage, (2) city refuse, (3) trade refuse. The city refuse, of which the city should provide for the collection and disposal, is separable into six classes:

Varieties of city waste.

1. Garbage—animal, vegetable and food waste from kitchens, markets, slaughterhouses, etc., principally water and putrescible organic matter.

2. Ashes—steam and household.

3. Rubbish—paper, wood, rags, metals, bottles, broken glass, sweepings from buildings and miscellaneous inorganic matter from houses and manufactories.

4. Street sweepings—animal manure, pavement dirt, droppings from carts, materials from building construction, leaves,

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 219.—Charlottenburg, near Berlin.—Watering-cart and Rubber Squeegee for Cleansing and Drying the Streets. June, 1909.

and other waste materials collected from the sidewalks and roadways.

5. Dead animals.

6. Snow—including the resulting ice and slush.

To dispose of the dirt which soils the streets, two general methods exist: It must be picked up and hauled away in carts or it must flow with water into the sewers.

In some cities, notably Paris, the sewers have been built with the idea of carrying off all the street dirt that can reason-

(*Courtesy of "The Engineering Magazine."*)

FIG. 220.—Two-ton Sprinkling Wagon used in Berlin.—Mann's (English) Steam-driven Street Sprinkling Wagon.

ably be emptied into them, but the best engineering opinion is that a city's sewers can, and should, be made to carry off only the fine dirt from the streets; the large, bulky, heavy particles must be removed otherwise.

Good pavements in good repair are indispensible to good work in street cleaning.

Comparative cleanliness of pavements.

The easiest to clean, but the pavement which requires the greatest amount of attention, is asphalt. Macadam is the most expensive pavement of all to keep clean. Wood-block pavements are more expensive than asphalt and less expensive than granite block to keep in good sanitary condition. Fine, dusty dirt is most conspicuous on asphalt. A good granite pavement has a capacity for holding a considerable quantity of fine dirt in its small irregularities without causing the remainder to be offensively apparent either as dust or mud.

Orderlies.

To remove large particles of refuse from the street pavements, the custom both in Europe and America is to employ handworkers. Their object is to pick up papers, horse droppings, and other refuse which they can easily and quickly remove, and to leave the pavement without conspicuous litter. In many European cities these workers are boys; in America they are often old men.

The refuse thus collected is put into barrels, bags or handcarts or thrown temporarily into bins or pits situated inside the curbline. In American cities small metal barrels are carried through the streets on light carriages which the workman pushes along before him.

Machinery employed in street cleaning

Although the hand-workers are usually provided with shovels, iron scrapers, and brooms, and in some cases hand-propelled sweeping-machines, they do not and cannot remove all the dust and mud which it is desirable to remove from a city pavement. This can only be done by the use of water. Nor can hand workers compete with horse or motor-propelled rotary brooms in removing large amounts of dirt from the pavements. Handwork is best on pavements which are in poor repair. In machine work the secret of success lies in having unob-

structed streets and good pavements, but the attempts made to use sweeping-machines are often decidedly crude. The brooms are not always preceded, but are sometimes actually followed, by sprinkling-carts. Too often no sprinkling accompanies the sweeping, the result being that dirt is raised through the air in clouds of dust to settle again upon the pavements and in the houses. Hand-sweeping is open to the same objection, for when sprinkling is done by persons

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 221.—Hamburg.—Street Cleaner with Apparatus about to Empty a Hand-cart Full of Sweepings into a Temporary Storage Pit Beneath the Sidewalk.

in connection with this work, it is often perfunctory and ineffective.

The facility with which street dirt may be removed from pavements and carried through the sewers in the presence of an abundance of water should be remembered when showers and rainstorms occur. At such times a street-cleaning force can, with hose or with simple rubber hand scrapers, clean an immense amount of fine refuse from asphalt streets by way of the sewers with comparatively little expenditure of energy

and of water; but instead of taking advantage of the opportunity, most street-cleaners seek shelter on the approach of rain.

One of the most efficient ways used in Europe for cleaning smooth pavements, such as asphalt, is by means of abundant water, speedily followed by scraping with rubber squeegees. In this case the dirt is first lubricated, then scraped away and the pavements partially dried by the scraping. Machine-scrapers hauled by horses are widely employed in Europe to clean asphalt streets. Where the amount of dirt on the pavement is large, most of it should first be removed by brooms before the more thorough cleansing with water begins. One of the advantages of scraping with rubber squeegees is that it leaves the pavements comparatively dry.

There is usually a lack of system and method about the whole undertaking of street cleaning in American cities, but in European cities the streets are well cleaned and the pavements are kept in good repair. It is recognized by the authorities that not only is the cost of cleaning dependent upon the condition of the pavements, but also that it is quite impossible to keep bad pavements clean.

Street cleaning authority

It is usual in the greatest cities for the heads of street cleaning departments to be engineers who have had considerable experience in this class of work, as the cleaning and removing of refuse from the streets is recognized to be one of first importance among municipal sanitary undertakings and a proper performance of the work of managing a street-cleaning department is considered to require thorough competence and a long training.

The street-cleaning department is often a branch of a larger department which has charge of the construction and repair of all structures between the house lines.

In the city of London the control of street conditions by the central authority is so complete that it includes not only street cleaning and refuse removal, but the construction and maintenance of sewers, sidewalks, pavements, fire hydrants, public comfort stations, subways for purposes other

than passenger transportation, lighting, the removal of dangerous structures, the erection of scaffolds for building purposes, and even the care of public clocks. This authority is called the Public Health Department and the work is done under the direction of an engineer of high standing. In other large cities the control of various matters which have to do with the condition of the streets, is also much centralized.

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 222.—Amsterdam.—Modern Type of Metal Dumping Wagon Fitted with Crane for Raising Heavy Receptacles.

That the great cities of Europe are cleaner than the great cities of America is due largely to the quality of the labor employed; much depends upon the capacity of the ultimate personal unit. In Germany the streets are cleaned by Germans; in France by Frenchmen; in England by Englishmen; in America by Italians, Irishmen, negroes and often by persons who have lost caste in every community.

Considerable difference exists in different cities concern-

ing the organization of the forces engaged in cleaning the streets, particularly as to the number of men employed and the extent to which military discipline prevails among them. In German cities it is the rule to employ workmen who have done military duty, and in most places none but men of good physique and energy are used. In some other countries it is evident that much less care is exercised with regard to the physical qualifications of the workmen; occasionally men can be seen who are superannuated and in other ways incapable, and in a few small places on the continent women take part in the work of street cleaning. In all cases responsibility is assigned in the street forces very much as in military organizations. At the head is a superintendent who has officers under him upon whom he can rely for a prompt and competent execution of his orders. These officers are in turn above foreman and working foremen who come in close touch with the actual work.

Organization of forces.

In the cities which have the cleanest streets there are usually two divisions of the work of cleaning—day and night work. The efforts in the daytime are usually directed chiefly toward removing refuse which, when scattered about, make streets appear disordered and dirty. The work of more careful cleansing is done at night. This consists in watering the streets and then either sweeping them with horse brooms or horse-propelled squeegees, or flushing them with a stream from a hose accompanied by work with hand brooms or squeegees.

In every case the cleaning begins by a thorough sprinkling of the streets—in some cities this covers the sidewalks. In Paris the preliminary wetting is followed by sweeping with a rotary broom and in many cases by squeegees propelled by horses. Rotary brooms, and rotary or fixed rubber squeegees hauled by horses, are used in nearly all cities.

In Paris, much street dirt is flushed into the sewers, which are unprovided with catch basins, and when built were intended to be sufficiently capacious to carry off all the refuse which might get into them. In other cities much of the

finely comminuted street refuse goes to the sewers also, but some of it is caught by catch basins.

The custom of flushing gutters exists generally throughout Europe in cities of every size, but Paris makes the most use of it. In London the streets are flushed every night, except when the weather is so cold that ice might form.

(*From Soper's "Modern Methods of Street Cleaning."*)

FIG. 223.—Antwerp.—Sprinkler, Sweeper, and Collector for Street Dirt.

Flushing.

As the methods of street cleaning differ in different cities, so there is great diversity among the types of apparatus employed. Motor-propelled water wagons of large capacities are in use in London and Berlin. In Antwerp there is a machine which sprinkles the street, sweeps it, picks up the refuse and carries it away. Mechanical sweepers,

however, cannot dispense with hand labor. Moreover, they require a fairly smooth pavement to work well.

The material swept from the streets of foreign cities is sometimes turned to advantage, but the principal object is understood to be to get it out of the way. Theoretically of much value as a fertilizer, and possibly of some use as a fuel, the practical difficulties of utilizing its useful ingredients are too great to make it of substantial benefit.

Disposal of street dirt.

In Paris, the refuse from the streets is, as far as practicable, swept into the sewers and carried with house drainage to farms or emptied into the River Seine below the city. Some of this refuse and other solid matters which are carried by the sewage have to be removed before the sewage is utilized.

The most usual way to dispose of street dirt is to use it to raise the level of low-lying land. Some difficulty is experienced in this direction, for there is not always suitable land to be filled. Furthermore, unless the refuse contains a large amount of indestructible matter, such as sand, it is not generally considered wholly suitable for this purpose. In many instances, where transporation is cheap because of special canal or river facilities, street sweepings are barged away to the country with other city wastes.

Removal of household refuse.

An important part of the work of the street-cleaning department is the removal and disposal of house refuse. It is an almost universal custom to collect this refuse in a mixed condition, but the component parts of the mixture vary in different cities and at different seasons of the year.

More or less sorting of refuse is done nearly everywhere and in some places to an extreme limit. In Paris, the household refuse is sorted by ragpickers upon the sidewalks, by men and women in the carts which collect the refuse from the houses and at depots in the outskirts of the city where the material is hauled.

In most British cities house refuse is thrown by the householders into private pits where it remains for periods of time ranging from a few days to several months. On the Con-

tinent portable cans and boxes are more often used. In some instances the cleaning department furnishes receptacles, carrying them away from the houses when full and returning them empty after they have been cleaned and disinfected.

In Great Britain the destruction of household refuse by burning in special furnaces was begun about thirty years ago and is now generally considered a desirable procedure wherever it can be followed.

To partly offset the cost of burning refuse, efforts are usually

(From Soper's "Modern Methods of Street Cleaning.")

FIG. 224.—Where Street-cleaning is unknown —Highway between Vollendam and Edam, Holland.

made to utilize the heat produced to raise steam for producing electric light, to pump sewage or water, to operate machines, and for many other purposes. The residue is used for such purposes as the making of concrete, mortar, bricks, and asphalt pavements.

Summary.

On reviewing the different subjects thus briefly covered, a number of points which go far to account for good results should be particularly mentioned. Most of these points have a general application to American conditions.

1. Centralization of responsibility for the repair and cleaning of street pavements is desirable.

2. A competent person should be at the head of the street-cleaning department—preferably an engineer experienced in sanitary work.

3. An organization somewhat military in character is best. But it is unnecessary that the military spirit should be carried beyond the point required to fix responsibility and insure a proper execution of orders.

4. Good pavements in good repair are indispensable to efficiency and economy in street cleaning.

5. Asphalt is the easiest pavement to clean, but the hardest to keep looking well because it will not hide dirt.

6. It is possible to clean streets without the use of water, but the results are only measurably satisfactory in most instances. For the best work there should be sufficient water used to carry off the finer dust by the use of water from a hose preceded by thorough lubrication with water from a sprinkling cart.

7. Sewers should be used to carry away all street refuse and sand which can be put into them without obstructing them or adding seriously to the problems connected with the disposal of the sewage.

8. Economy demands that refuse be removed as soon as possible after it is produced and unnecessary littering prevented.

CHAPTER XX

SIDEWALKS, CURBS AND GUTTERS

The term sidewalk, as ordinarily applied, refers to the pavement usually placed on the side of the carriageway pavement. Its object is to provide a serviceable roadway for pedestrians, and the conditions that render a road well adapted to its purpose are very much the same as those required for a walk. It is not subject to the effects of heavy loads such as use the roadway, but the destructive action of water and frost is the same in either case, and the various questions of economics, location, width, grade, and materials that affect the roadway must also have careful consideration in connection with the sidewalk.

In business districts the sidewalk usually extends from the building line to the curb. On residence streets, however, it is not so important to use this full width and there is a choice of location, as to whether it be brought up to the property line and the curb, or a distance from either or both to allow a margin of grass and a row of trees.

The width, exclusive of any space occupied by grass and shade trees, should be sufficient to comfortably accommodate

Width.

the traffic. On business streets this should be at least one-third the width of the carriageway, and on residential streets, from 4 to 6 feet is the usual width, except where the streets are solidly built up with houses several stories high, when the walk should be 8 or 10 feet wide, or in case the walk is used as a promenade or an important thoroughfare, when the width is even greater.

There should be a surface-slope from the property to the

Slope.

curb, to shed water toward the gutter, varying from 1 inch in 3 feet to 1 inch in 5 feet, according to the roughness of the surface, and the longitudinal

slope should conform, as nearly as practicable, to the grade of the street.

Foundation. The foundation is of as great importance as in roadways. Whatever material may be used for the surface, if the foundation is weak and yielding the surface will settle irregularly and become extremely objectionable, if not dangerous, to pedestrians.

Requirements of a good walk. The principal requirements of a good sidewalk are:

1. Smoothness, but not so as to be slippery.
2. Non-absorbent of water, so that it may dry rapidly after rain.
3. Not easily abraded.
4. Uniform quality throughout, so that it may wear evenly.
5. Must neither scale nor flake.
6. Durability.
7. Low in first cost.

Of these 1, 2, 6 and 7 are the most important.

Materials used. The materials most generally used for sidewalks are: asphalt, brick, cement, concrete, cinders, gravel, macadam, stone slabs (natural and artificial), tar concrete, and wood planks.

The relative order of these materials as compared with the essential requirements is as follows:

Smoothness:	*Readiness of drying:*	*Durability:*
Asphalt and cement	Asphalt and cement	Brick
Stone slabs	Stone slabs	Cement
Brick	Brick	Stone slabs
Plank	Plank	Gravel and macadam
Gravel	Macadam	Asphalt
Macadam	Gravel	Plank

Cost varies with the locality and the form of construction so that it is impossible to give their rank except in particular cases. While stone slabs have been most common in the past, cement and brick are now the most used materials, the former where a first-class walk is desired and the second where cheapness is a prime requisite. Roots of trees damage brick walks much less than those made of cement.

Of the natural stone, sandstone is most extensively used.

This forms an excellent paving material, standing high in all the necessary qualifications of a good sidewalk. It is found in the quarries in layers of from one inch to three feet in thickness, and is used in all sizes, many of the slabs used for flagging in New York being 20 feet long, 15 feet wide and 8 to 10 inches thick, while blocks from 25 to 60 feet long are often lifted from the bed. A walk made of split flagstones is ordinarily a little smoother than one made of brick, but is not so smooth as a cement walk.

Sandstone.

FIG. 225.—Section of Suburban Street, showing Broken-stone Roadway, Paved Gutter, Tile Drain and Gravel Walk.

Granite

Granite is also extensively employed; it is durable, but is expensive and wears slippery, so that its surface must be frequently roughened to keep it in a safe condition.

Wood.

Wood planks have long been used for sidewalks, especially in small communities. They are cheap, but not durable, and they require constant repair to keep them from becoming dangerous. They were more common in earlier days when the cost of wood was low, but in later years, owing to its increasing cost and to the comparatively low cost of brick and concrete, board walks are much less common than formerly.

Brick.

Brick sidewalks are very common and when well made are cheap and durable and make an excellent footway for residential streets or for the business streets of smaller towns. They consist ordinarily of hard-burned building brick laid upon a porous bed of sand or cinders, but

in districts where the travel is heavy, the bricks are set on edge and the joints are filled with cement mortar. The ordinary building brick is, however, not suitable, as it soon wears out and breaks; hard-burned paving brick, with plane parallel surfaces and sharp right-angled edges should be used,

(a) Longitudinal Herring-bone Method.

(b) Diagonal Herring-bone Method.

(c) Square-course Method.

FIG. 226.—Methods of Laying Brick Sidewalks.

and great care must be exercised in the method of laying the bricks to prevent unevenness.

Bricks are very advantageously and extensively used for street crossings on unpaved streets and on streets paved with stone block, in the former case to provide a clean crossing for pedestrians and in the latter to provide a smooth surface.

"Brick sidewalks are cheap, fairly smooth and not slippery; and if made of hard brick are dry in damp weather and durable

under very heavy travel. Their defects are: (1) they are rough in comparison with asphalt, cement and the best stone slabs; (2) they are untidy, since grass and weeds are likely to grow in the joints." *

Artificial stone.

Artificial stone is extensively used. There are many varieties manufactured under different names and subject to several patents, the most common being those known as: granolithic, monolithic, and kosmocrete. When well made and placed with proper drainage provision, any one of these forms a durable, inexpensive and altogether satisfactory pavement.

Gravel.

Gravel is largely employed for walks in suburban streets,

Fig. 227.—Section of Park Walk, showing Manner of Removing Surface Water.

country roads, parks and pleasure grounds, principally because of the natural harmony of its color with such surroundings and because of the informality and ease of its appearance as compared with asphalt and cement. This method of construction is substantially the same as in the case of gravel roadway pavements. A good example of the adaptability of gravel for pathways is found in the case of Central Park, New York, where they are laid on every variety of ground from level and smooth to rocky and precipitous, winding along rugged hillsides; gently undulating over meadows and lawns, and sometimes expanding into broad and capacious promenades. They are carried over and under roads, and over brooks, by archways and bridges of various kinds,

* Baker, "Roads and Pavements," page 602.

ornamental and rustic; through rough gorges and ravines, and along the water edge of lakes and ponds. They are made in various widths from 3½ to 35 feet, and adapted to nearly every circumstance of position, locality, use, and convenience that ordinarily occurs in walks for rural or park purposes.

FIG. 228.—Cinder Path, Lehigh University Campus, So. Bethlehem, Pa

The principal causes of the deterioration of this kind of walk, and the greatest source of trouble and expense in repairs, is the wash from water brought from the adjoining slopes. Sometimes a single shower will cause damage that will involve a heavy expense for repairs, so the necessity of liberal and ample provision to guard against this trouble will be seen to be warranted by sound economy.

The most permanent form of sidewalk and the form that is daily growing in favor is of Portland cement construction.

Cement and concrete.

The Portland cement concrete sidewalk, when properly constructed, meets all the requirements of evenness, solidity and permanency, and in practically all localities, can be built at a comparatively low cost. The possibilities of concrete are well appreciated, but often, through lack of knowledge of the material and inexperience in handling it, many walks are built which, sooner or later, become more or less defective.

There are certain rules which should be observed in all cases, and in some cases additional precautions are necessary. The

(a) Improper Construction. (b) Proper Construction.

FIG. 229.—Method of Constructing Driveway Across Walk.

location of a walk is determined regardless of the natural fitness of the foundation, the soil and drainage conditions, and it is important, therefore, that these matters be carefully studied; materials available should also receive careful attention, their selection being made with reference to quality rather than with reference to cost. Weather conditions seriously affect the behavior of concrete and must be taken into account to assure permanence of the walk. Poor workmanship, which includes improper proportioning of materials, the placing of a walk on an improperly prepared foundation and failure to take into account weather conditions, is responsible for practically all failures that occur. Very few cement walks, if any, have been worn out.

Cement sidewalks are usually made of cement stone slabs

framed in place on the job.* To accomplish permanency, it is necessary that these slabs remain hard, tough and in the original position, and to achieve this, methods of manufacture must be employed which will avoid settlement cracks, upheaval by frost, crumbling due to work done in freezing weather, contraction and expansion cracks, separation of top from base, and disintegration.

A great many walks have slabs warped into saucer-like shapes, without any signs of cracking, which slabs, unless the walk is on a grade, act as basins holding water after each rain. These warped slabs occur both in walks of large area made up of a number of rows and in single slab suburban walks flanked by lawns. In the latter case there is, in addition, usually a longitudinal crack along the center of the walk, as shown in Fig. 230. Suburban walks flanked on one side by a terrace are generally the worst. A great many walks are cracked at curved corner curbs, and at the ends of walks next to the curb at cross streets; often slabs in the middle of long walks buckle up, as shown in Fig. 231. In many cases the expansion in the cement walk has either pushed the curb out of line or broken it off entirely.

In concrete walks, as usually built, the earth is excavated to 10 or 12 inches below the finished surface and 6 or 8 inches of cinders are laid for foundations on which the 3-inch concrete walk is laid, with a 1-inch cement covering surface. When no additional drainage is provided, water enters the foundation of the walk through the lawns on either side, and at all the joints between the slabs. Naturally, this moisture is greatest at the sides and near the joints, where its enters, very little reaching the center of the slab. Subsequent freezing causes greater upheaval of the foundation near the edges of the slab than at the suspended center, and the slab finding bearing only on the edges, acts as a beam. The load, while not great, is applied continuously and simultaneously, with changes in

* Correct methods of construction are avaliable in the form of trade pamphlets issued for gratuitous distribution by several of the leading cement companies, and there are also several cheap books devoted exclusively to this subject. (See Bibliography, Appendix V.)

FIG. 230.—A Longitudinal Crack; a Common Failure.

temperature, and finally causes a flow of the material, resulting in depression and permanent set.

The dissimilarity in density of the concrete base and the top coat or wearing surface, which causes a different ratio of

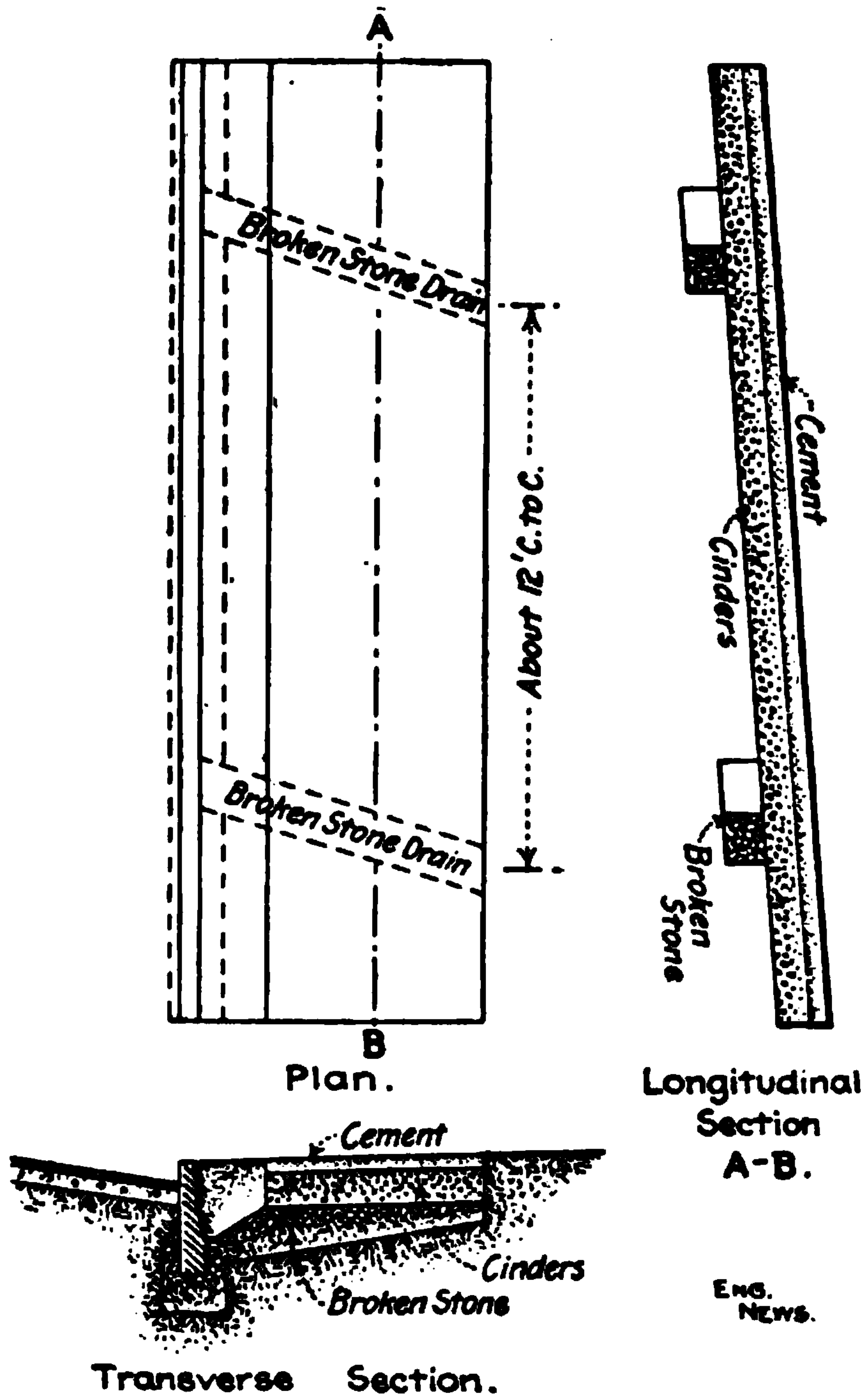


FIG. 231.—Details of Drains for Concrete Sidewalks.

expansion and contraction in the base from that in the top, also results in warping.

Sub-foundation and drainage. To avoid this sagging and upheaval, perfect drainage in the sub-foundation is of utmost importance. Fig. 231 represents a walk in which drainage is taken care of by trenches about 10 inches deep and of a convenient width across the sidewalk, extended to the curb, and filled with broken stone. The ditches are dug across obliquely, so as to take advantage of the slope of the

Fig. 232.—A Buckled Slab Due to Expansion.

sidewalk. Fig. 233 shows a section of concrete walk as specified by the city of Pittsburg, which provides an outlet for drainage to the curb somewhat like that on Fig. 231.

Upheaval by tree roots.

Upheaval by tree roots can very easily be avoided by cutting out any roots which will run under the pavement less than a depth of six inches under bottom of drainage foundation.

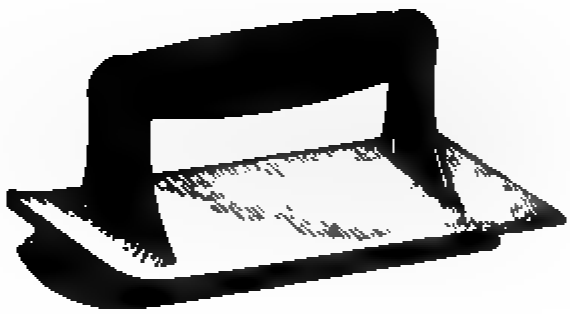
Foundation.

Broken stone and gravel are sometimes used for foundation, but cinders are most frequently used and are preferable. The thickness of the cinder foundation required varies in the different city specifications from 4 to 12 inches. A thickness of 6 inches is ample. A greater thickness, unless deep enough to go below the freezing line,

FIG. 233.—Suggested Design for Concrete Sidewalk.

would really be detrimental, as the upheaval of frozen cinders would be proportional to its thickness. Cinders that have been placed in a walk for some time before placing the cement should be picked loose and retamped so that the entire mass has even compaction. If some places are packed harder than others, the flag will not have an even bearing and may break. One of the causes of inferior concrete in the base is the absorption of water from the mixture by the porous foundation before it has set; therefore, a thorough wetting of the foundation just before placing the concrete is desirable.

The concrete in the base of concrete walks is generally the most inferior concrete made. The capital and equipment necessary for doing this kind of work is comparatively small, and the construction work apparently easy, the result being



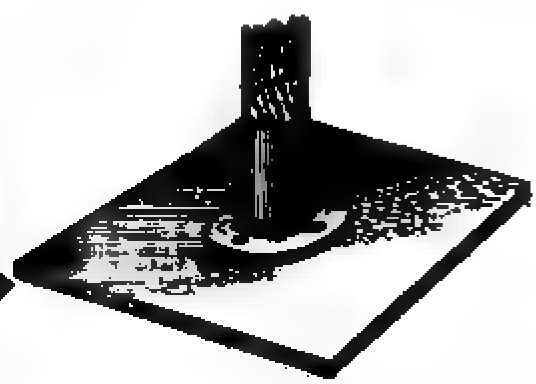
Groover.

Finishing Trowel.

Roller.

Blade for Cutting Concrete Base.

Edger.



Rammer.

Fig. 234.—Tools used in Construction of Concrete Sidewalks.

that many walks are put down by inexperienced contractors and competition has reduced the price so that good work cannot be done profitably. But even with as good material and workmanship, it is hardly possible to get as good concrete in cement sidewalk base as in structures of larger volume, such as retaining walls, abutments, etc., as in tamping a thin layer of concrete laid on a cinder bed, the concrete may compact a little under each blow, but a great part of the force is expended in forcing the concrete up at another place and possibly dislodging the cinder bed. This is one of the reasons why it is necessary to have the cinder bed thoroughly compacted before placing concrete, and why it is advisable to so mix the concrete and have it of such constituency as to reduce the amount of tamping necessary.

Concrete base.

Insufficient water is often used in mixtures for concrete base. More water should be used, and thorough mixing adhered to, as well-mixed concrete is more dense than poorly-mixed and requires less tamping.

A great many failures are due to a lack of bond between the top coat or wearing surface and the concrete base. In the laying of the walk, and in order to accomplish much work, the concrete base is sometimes allowed to get its initial set before applying the top coat, consequently there is little bond, the upper wearing surface becomes loose and easily breaks. If the upper surface of the base is troweled or smoothed off, the strength of the bond is reduced; it is important, therefore, to leave the base free of troweling.

Top coat.

When concrete walks were first laid, forms defining the blocks were used and the concrete placed in alternate blocks. When these had set the remaining spaces were filled in. This scheme made positive joints and prevented breaking of flags on account of settlement. While this is still required in some specifications the greater proportion of work is done in continuous sheets, the walk being cut at the joints by a knife and sledge. Some specifications require the joint to be filled with sand and the surrounding concrete tamped, and others require tar paper put into joint. After the top coat or wearing surface is put on, it is cut through

Joints.

Fig. 235.—Curb Broken Away by Expansion, showing Necessity of Expansion Joints.

Fig. 236.—A Miserable Piece of Sidewalk Construction.

Apparently every rule and precaution necessary for the production of first-class work was disregarded in the placing of this walk. The fill was insufficiently and improperly prepared and was not protected. The base was weak, failing to support the top, which was not bonded to the base. This is an extreme example of shoddy construction.

over the joint in the base. The cutting is often indifferently done and sometimes the cut through the wearing surface is not directly over the cut through the base. Then if there is any settlement the top will crack in an irregular line. Water will also get in at the joint under the top coat and freeze, causing it to break. The objections to laying the alternate blocks in a walk are that it is hard to get the different blocks in a true plane, the appearance, therefore, is not so good. Another objection is the increased cost and time required. It would seem that the method now most generally followed of building a continuous course and cutting up into blocks with a tool designed for that purpose is the best. The tool should be so shaped as to make the top edges of the groove firm, smooth and slightly round, and should be long enough to cut entirely through the top coat and the concrete base.

The greatest failures are from expansion, and to take care of this it is well, in addition to the block joints, to provide extra joints from 1 to 1½ inches wide about every 100 feet of walk when more than this distance is laid at one time; also at the ends of walks next to the curb at cross streets and along the curb where the sidewalks are very wide and have curved curb corners. These joints are usually filled with sand. It is not necessary or desirable to have sharp sand; sand with rounded grains will answer better. Pitch and asphalt have also been used for the large joints and will prevent to some extent moisture reaching the cinder bed.

The size of the blocks should be limited to about 6×6 feet. When the sidewalk extends from a building to the curb or in subways from the abutment to the curb or curb wall, as the case may be, the cement walk should not be built tight around the building, abutment, curb or curb wall, but an open joint about 1 inch wide should be left. There is likely to be some settlement in either the building, abutment, curb, curb wall or sidewalk and irregular cracks will result.

Some cracking is caused by the upper surface of the walk drying out faster than the bottom, acting very much as dried mud in a river bottom, where the sun dries the top first, which shrinks and breaks up into small blocks. Subsequent shrink-

Fig. 237.—Section of Walk showing Careless Construction.

Fig. 238.—Showing Change of Grade.

The comfort of pedestrians demands that the grade in a walk shall not change suddenly excepting where steps are advisable

ing in the lower stratum only increases the width of the cracks. For this reason, it will be well to keep the top of the walk moist for several days during dry weather. It is known that wetting the surface will also produce a whiter walk than one that is allowed to dry out quickly.

Portland cement concrete sidewalks, when properly constructed, are no doubt superior to all others. The cost of construction is not much greater than other sidewalks, so that their more extended use depends upon their permanency. It is advisable, therefore, that the best material and workmanship be used so as to get best possible results.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE SIDEWALKS OF THE NATIONAL ASSOCIATION OF CEMENT USERS

MATERIALS.—The cement shall meet the requirements of the specifications for Portland cement of the American Society for Testing Materials, and adopted by this Association (Specification No. 1), January, 1906.

AGGREGATES.—Fine Aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-inch diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse aggregate shall consist of inert material, graded in a size, such as crushed stone or gravel, which is retained on a screen having ¼-inch diameter holes, shall be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles shall be excluded.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully filling all parts of the forms. The size of the coarse aggregate shall be such as to pass a 1¼-inch ring.

Water shall be clean, free from oil, acid, strong alkalies, or vegetable matter.

FORMS.—Forms shall be free from warp, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used.

The forms shall be well staked to the established lines and grades, and their upper edges shall conform with finished grade of the walk, which shall have sufficient rise from the curb to provide proper drainage; but this rise shall not exceed ⅜ inch per foot, except where such rise shall parallel the length of the walk.

All forms shall be thoroughly wetted before any material is deposited against them.

SIZE AND THICKNESS OF SLABS.—Slabs shall not contain more than 36 square feet or have any dimension greater than 6 feet. For greater area, slabs shall be reinforced with ¼-inch rods, not more than 9 inches apart, or other renifoorcement equally as strong.

The minimum thickness of the pavement shall not be less than 4 inches.

SUB-BASE.—The sub-base shall be thoroughly rammed, and all soft spots removed and replaced by some suitable hard material.

When a fill exceeding one foot in thickness is required, it shall be thoroughly compacted by flooding and tamping in layers of not exceeding 6 inches in thickness, and shall have a slope of not less than 1 to 1½.

The top of all fills shall extend at least 12 inches beyond the sidewalk.

While compacting, the sub-base shall be thoroughly wetted and shall be maintained in that condition until the concrete is deposited.

BASE.—The concrete for the base shall be so proportioned that the cement shall overfill the voids in the fine aggregate by at least 5 per cent, and the mortar shall overfill the voids in the coarse aggregate by at least 10 per cent. The proportions shall not exceed one part of cement to eight parts of the fine and coarse aggregates. When the voids are not determined the concrete shall have the proportions of one part cement, three parts fine aggregates and five parts coarse aggregates. A sack of cement (90 lbs.) shall be considered to have a volume of one cubic foot.

MIXING.—The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed, and the mass is uniform in color and homogeneous.

a. Measuring Proportions. Methods of measurement of the proportions of the various ingredients including the water, shall be used which will secure separate uniform measurements at all times.

b. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

c. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and especial precautions shall be taken to turn the materials until they are homogeneous in appearance and color.

d. Consistency. The materials shall be mixed wet enough to produce a concrete of such a consistency as will flush readily under light tamping, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

e. Retempering. Retempering mortar or concrete, i. e., remixing with water after it has partially set, shall not be permitted.

PLACING OF CONCRETE.—*a*. Methods. Concrete after the addition of water to the mix shall be handled rapidly to the place of final deposit, and under no circumstances shall concrete be used that has partially set.

b. Freezing weather. The concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

Sidewalks shall be laid in such a manner as to insure the protection of the pavement from injury due to changes in foundations or from contraction and expansion.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be carefully removed before the wearing surface is applied.

WEARING SURFACE.—The wearing course shall have a thickness of at least 1 inch.

The wearing surface shall be mixed in the same manner as the mortar for the base, but the proportion one cement to two of fine aggregate, and it shall be of such consistency as will not require tamping, but will be readily floated with a straight-edge.

The wearing surface shall be spread on the base immediately after mixing, and in no case shall more than 50 minutes elapse between the time that the concrete for the base is mixed and the time that the wearing course is floated.

After being worked to an approximately true surface, the slab markings shall be made directly over the joints in the base with a tool which shall cut clear through to the base and completely separate the wearing courses of adjacent slabs.

The slabs shall be rounded on all surface edges to a radius of not less than ½-inch.

When required the surface shall be troweled smooth.

The application of neat cement to the surface in order to hasten the hardening is prohibited.

On grades exceeding 5 per cent, the surface shall be roughened. This may be done by the use of a grooving tool, toothed roller, brush, wooden float or other suitable tool; or by working coarse sand or screenings into the surface.

Where color is used it shall be incorporated uniformly and the quantity and quality shall be such as to not impair the strength of the wearing surface.

SINGLE-COAT WORK.—Single-coat work shall be composed of one part of cement, two parts of fine aggregate and three parts of coarse aggregate, and the slabs separated as provided for in the specifications for two-coat work.

The concrete shall be firmly compacted by tamping and evenly struck off and smoothed to the top of the form. Then with a suitable tool the coarser particles of the concrete shall be tamped to a depth which will permit of finishing the walk as under "Wearing Surface."

PROTECTION AND GRADING.—When completed, the walk shall be kept moist and protected from traffic and the elements for at least three days.

Grading after the walks are ready for use should be on the curb side of the sidewalk, 1½ inches lower than the sidewalk, and not less than ¼-inch to the foot fall towards the curb or gutter. On the property side of the walk the ground should be graded back at least 2 feet and not lower than the walk; this will insure the frost throwing the walk alike on both sides.

CURBS.—The trench shall be excavated to a depth not greater than the bottom of the curb and a width not greater than the thickness of the curb plus 6 inches.

The thickness of the curb shall not be less than 6 inches.

After the forms are set about 1 inch of wearing surface shall be placed on the inside of the curb form, then the concrete shall be deposited at one operation and firmly tamped to within 1 inch of the top of forms. The top wearing surface shall then be placed and be of the same composition as that specified for sidewalks.

Joints shall be made three-fourths the depth of the curb, continuous with joints of the sidewalk and in no case more than 6 inches apart.

The forms shall be removed as soon as practicable and the faces finished at one operation, floating down 6 inches with a one to one mixture of cement and fine aggregate of sufficient thickness to produce a smooth surface.

Where a combination curb and gutter is required, they shall be cast at the same time and finished at one operation.

Curbs and Gutters

Curbstones. Curbstones are employed for the outer side of the footways to sustain the coverings and form the gutter. Their upper edges are set flush with the sidewalk, so that the water can flow over them into the gutters.

The disturbing forces which the curb has to resist are: (1) the pressure of the earth behind it, which is frequently augmented by piles of merchandise, building materials, etc., tending to overturn it, break it transversely, or move it bodily on its base; (2) the pressure due to the expansion of freezing earth behind and beneath it, especially where the sidewalk is partly sodded and the ground is accordingly moist, tending to thrust the curb forward; (3) the concussions and abrasions caused by the traffic, the defacement and injury to the curb from fires built in the gutters, and the breaking, displacing and destruction resulting from posts and trees set too near the curb.

The use of drain-tiles under the curb is a subject of much difference of opinion among engineers. Where the subsoil contains water naturally, or is likely to receive it from outside the curblines, the use of drains is of decided benefit, but great care must be exercised in jointing the drain-tiles lest the soil shall be loosened and removed and cause the curb to drop out of alignment.

The materials employed for curbing are the natural stones, as granite, sandstone, etc., artificial stone, fire-clay, and cast iron.

The dimensions of curbstones vary considerably in different localities, and according to the width of the footpaths: the wider the path the wider should be the curb. It should, however, never be less than 8 inches deep, nor narrower than 4 inches. Depth is necessary to prevent the curb turning over

towards the gutter. It should never be in less lengths than 3 feet. The top surface should be beveled off to conform to the slope of the footpath and the front face should be hammer-dressed for a depth of about 6 inches, in order that there may be a smooth surface visible against the gutter. The back for 3 inches from the top should be also dressed, so that the flagging or other paving may butt fair against it. The end-

Fig. 239.—View Showing Expansion of Concrete Sidewalk, Chicago

joints should be cut truly square, the full thickness of the stone at the top, and so much below the top as will be exposed; the remaining portion of the depth and bottom should be roughly squared, and the bottom should be fairly parallel to the top.

Setting curb requires care and an experienced workman,

for as it is set dry, great care must be exercised to set it true to level and line. It must be well rammed and bedded or it will sink, turn slightly over or move, even months after it has been set. Curbstones carelessly set will never present a pleasing appearance.

Setting curb.

Curbstones to be set in concrete should be first set and blocked in position on grade and line. The blocking should

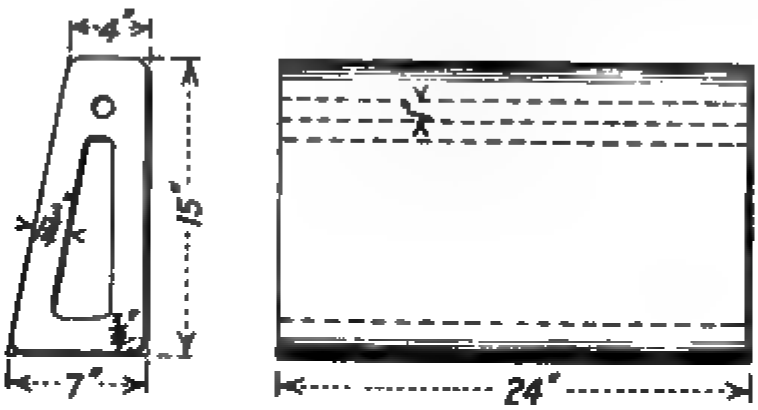


Fig. 240.—Vitrified Clay Block for Street and Road Curbing.
(See also Fig. 188, Chap. XV)

Fig. 241.—Concrete Curb and Gutter.

be done with brick, paving-stones, or other imperishable material.

For tamping the concrete under and around curbstones, a wooden tamper made of a piece of seasoned oak 2 inches by 4 inches, about 5 feet long, shod with $\frac{1}{4}$-inch iron, forms an excellent tool.

The concreting of the curbs (which should be done in advance of the roadway concreting) is best performed by first filling

underneath from the roadway side, then upon the face and back up to the grade of the roadway; then filling up behind the stones to the required height, removing all blocking as the concrete is tamped in, taking care not to disturb the alignment of the curb and to see that every space is filled solid with the concrete.

In setting curbstones the ends should be kept from actual contact, by strips of $\frac{1}{8}$-inch iron temporarily inserted as they are set and, after the roadway concrete is laid, the joints should be filled with a thin grout composed of equal parts of Portland cement and sand. This should be done by first

FIG 242.—Concrete Curb and Gutter.

pressing a small amount of stiff mortar into the joints at the face and back and then pouring the grout in from the top until the joint is full. If these joints are not filled solid, but simply smeared over the surface with a little mortar which penetrates but a half-inch or less, it will only be a question of a short time when it will drop off and leave a cavity between the stones.

In localities where stone is not obtainable, artificial stone, fire-clay curb, and cast iron afford excellent substitutes. Fire-clay curbing is extensively used with brick pavements.

Cast iron cast in L-shaped sections is employed in some cities in France.

In streets covered with broken stone, a stone gutter is

necessary. It may be formed of either stone slabs or paving-blocks, the latter being the better, and it should **Gutters.** be not less than 18 inches wide. If formed of paving-blocks, the blocks should be laid with their length parallel to the curb, bedded on gravel, and well grouted in with bituminous cement.

When stone slabs are used, they should be not less than 3 feet long, 6 inches thick, and from 10 to 15 inches in width. They should be laid so that they will not be of uniform width,

Fig. 243.—Type of Concrete Curb with Slanting Outer Face. Used in Country Work.

otherwise the continuous longitudinal joint between the gutter and the rest of the pavement will quickly wear into long deep ruts or grooves, causing severe strains upon the running-gear of vehicles when attempting to leave it.

The gutter should have the same slope as the roadway, and the curb should show 7 inches or more above it.

In streets paved with asphalt, granite blocks, or bricks the same material is used for the gutters; the blocks being laid with their length parallel to the curb, instead of transversely as in the street itself.

Street-crossings are formed of two or more rows of stone

slabs, usually with one or more rows of paving-blocks between them. The stone used should not be less than 3 feet long, 10 inches wide, and 6 inches thick, with the top surface hammer-dressed, the ends cut to a bevel of about 15 degrees, and dressed so as to form a close joint for the full depth of the stone. The reason for beveling the joints is to cause the traffic to travel across the joint instead of along it, and thus prevent the formation of the ruts which happens with right-angled joints. The beveled joints must point towards the center of the intersection, otherwise the desired result will not be obtained, and ruts will be formed.

Crossing stones.

CHAPTER XXI

MISCELLANEOUS ROADS AND PAVEMENTS

Stone trackways.

STONE trackways were used in ancient Egypt for lowering the tractive resistance in moving great weights, and in modern times they have been used in nearly every European country and in America. (See p. 8.) Their use on an extensive scale has, however, been abandoned except in Northern Italy. Those in use in Italy consist of two parallel lines of granite blocks, 14 inches wide by 8 inches deep by 5 feet long, bedded in a layer of sand. The lines are 28 inches apart, with a footway for horses be-

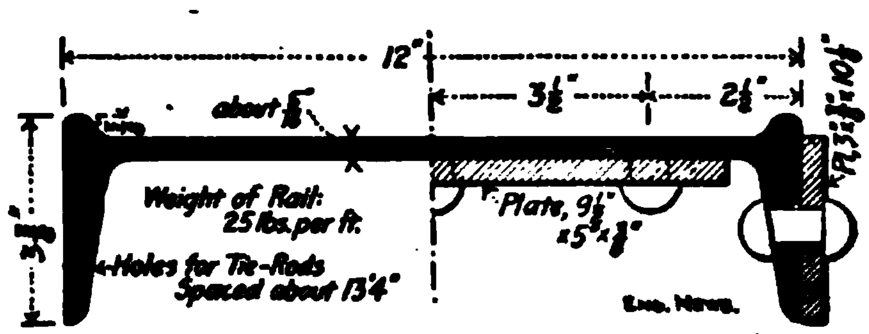


FIG. 244.

tween, paved with cobbles. This footway has a slight inclination downwards towards the center, thus serving as a channel to receive the surface water, which finally escapes into the sewers through stone gratings.

Steel trackways.

The steel trackways that have been constructed consist of two parallel lines of steel plates, 8 inches wide, laid at a sufficient distance apart to receive the wheels of vehicles of the standard gauge. The plates are provided on one edge with a flange ½ inch wide, and on the under side with a flange about 6 inches deep, which, when bedded in the earth of the roadway, supports the rail without the use of cross-ties. Tie-rods are used at intervals of about 10 feet.

The advantages claimed for the steel-track wagon road are: (1) that it can be built without greater cost in most cases, and probably with less cost in many cases, than any other hard and durable road; (2) that it will last many times as long as any other known material for road purposes and with much less repair; (3) that the power required to move a

FIG. 245.—The Steel Track as a Bicycle Path.

vehicle over the steel-track road is only a small fraction of the power required to move the same vehicle over any other kind of road.

During 1892 a steel trackway was constructed between Valencia and Grao, Spain, to replace a stone road which cost $5470 a year to maintain. It is traversed daily by an average of 3200 vehicles, each of which pays a toll of about eight-tenths of a cent, and the annual cost of maintenance is about

$380, but for various local reasons this cannot be taken as a guide for American practice.

In regard to durability, the claim is true only as far as the steel rails are concerned, as the surface adjoining the rails, whatever it may be, will in a comparatively short time, be worn into ruts by vehicles turning on and off the steel rails.

The most serious disadvantages of the steel trackway is that if it does not have a permanent footway for the horses, it is least effective in a muddy time, when it is most needed; and if it does have a permanently hard surface between the rails, the cost is unreasonable. If a steel trackway is laid in a broken-stone road, the additional cost will be (1) the cost of the metal, (2) the cost of placing the metal, including the increased cost of compacting the broken stone, and (3) the increased cost of maintenance.

Another objection is that owing to the narrow space between the rails, the horses are compelled frequently to step upon the rails, the smooth surfaces of which interfere with their footing, which in a measure neutralizes the advantages of a smooth track for the wheels. Still another objection is that the gauge of vehicles varies considerably, and consequently either the face of the rail must be very wide, which increases the expense, or some vehicles cannot be accommodated. The conclusion is, therefore, that trackways are out of date, that they are more expensive and less effective than good macadam roads, and that for a country where an ordinary macadam road does not suffice, a first-class pavement or a railroad should be built.

Concrete-block trackways.

Concrete blocks have frequently been experimented with in connection with trackways, but their uses for horse-propelled vehicles are subject to the same, or even more serious, disadvantages, as the stone and steel trackways. Their use has, however, been successful in connection with automobile traffic, by decreasing not only the resistance, but also the wear on the road and the cost of maintenance.

Fig. 246 shows a section of a concrete-block trackway built

FIG. 246.—Concrete-block Trackway, Orlando, Fla.

FIG. 247.—Reversible Concrete Block.

Fig. 248.—Road Making as a Fine Art.

Laborers engaged in building a special motor-car road in Paris, each individual bit of stone being carefully placed by hand.

near Orlando, Florida, which, in two years of continual use, required no repairs.

The block is 12 inches wide, 8 inches thick, and 24 inches long, with a groove 1½ inches deep and 6 inches wide at the bottom, curving in a convex form to the flange on the outside, the flange showing a surface of 2 inches. When laid, the surface of the flange should be flush with the surrounding soil. The blocks are held together with a tongue and groove arrangement that keeps the ends from working up or down, and the flange on the bottom of the block keeps it from having any side motion, every block being thus held rigidly in position. The blocks are reversible, so that when one side shows any effect of wear, it can be turned over and the road given a new surface.

It is claimed that heavily loaded wagons can be turned out of this track road with little difficulty, without the road suffering from such wear. The block are made of carefully mixed and tamped concrete and can be made along the road on which they are to be used, and if sand and gravel of good character are near the highway, the road can be resurfaced at very low cost.

Artificial granite blocks.

Artificial granite blocks are formed from the chippings of granite quarries, mixed with Portland cement in sufficient quantity to make a thorough bond between the pieces. It is put down in blocks or squares, and the surface is kept comparatively rough by the cement wearing below the points of the granite. Its only advantage is cheapness.

Plank roads.

In localities where timber is abundant and other materials are unobtainable, planks may be employed to form pavements. The first plank road on the continent was built in Canada in 1836; they then became somewhat common in the heavily timbered portion of the northern United States and of Canada, and were very advantageous in the building up of new districts, but very few of them are now in existence.

When new and when kept in repair, plank roads make a comparatively smooth roadway possessing some advantages

for both light and heavy traffic. The planks are, however, very likely to be displaced, even when spiked down, and are likely to be floated away, when not spiked down, and when in this condition they make a very disagreeable road. Maintenance is expensive, as being alternately wet and dry, the plank rots rapidly and at best does not last more than five years, and often only two.

In construction, plank roads are usually about 8 feet wide, and occupy one side of an ordinary earth road, the other side being used to turn out upon and for travel during the dry season. The method of construction most commonly followed is to lay the boards perpendicular to the axis of the road, as this position is more favorable to their wear and tear than any other, besides being the most economical.

Their ends are not in an unbroken line, but so arranged that the ends of every three or four project alternately, on each side of the axis of the road, 3 or 4 inches beyond those next to them. This presents a short shoulder to the wheels of vehicles to facilitate their coming upon the plank surface when they may have turned aside and prevents the formation of long ruts at the edges of the road. Often the boards have been spiked to the sills, but this is unnecessary, the stability of the boards being best secured by well packing the earth between and around the sills, so as to present a uniform bearing surface to the boards, and by adopting the usual precautions for keeping the subsoil well drained and preventing any accumulation of rain-water on the surface. The boards were often covered with gravel, sand, or loam to protect them from wear.

Corduroy roads.

Corduroy, or log, roads are make-shifts employed in timbered districts to carry a road over soft, swampy ground always kept moist by springs and which cannot be drained without too much expense. They are built by felling a sufficient number of young trees, as straight and as uniform as possible, and laying them side by side across the road at right angles to its length. Though its successive hills and hollows offer great resistance to draught and are very unpleasant to persons riding over

it, it is nevertheless a very valuable substitute for a swamp, which in its natural state would at times be utterly impassable, and with sufficient care such roads may be made fairly smooth when new, but they grow exceedingly rough with age.

Charcoal.

In some of the Western States, where wood is abundant and cheap, and gravel scarce, roads for light traffic have been made by felling and burning the timber, and covering the road with the charcoal. Poles from 6 to 16 inches in diameter are cut and piled lengthwise along the road about 6 feet high, being 9 feet on the bottom and 2 on top, and then covered with straw and earth, or simply with sods, and burned in the manner of coal-pits. The covering is taken from the sides of the road, and the ditches thus formed afford good drainage. After the timber is converted into charcoal, the earth is removed to the side of the ditches, the coal raked down to a width of 15 feet, leaving it 2 feet thick at the center and 1 foot at the sides, and the road is completed. The charcoal, being soft and friable, should be covered with a thin layer of earth or gravel for greater durability, and to prevent it from blowing or washing away.

Slag roads.

Slag and cinders from iron and copper works may be employed with advantage when they are procurable, and when no stone sufficiently tough to withstand the action of heavy traffic can be obtained. The slag from modern steel furnaces is comparatively light, has a sponge-like structure, and contains a large amount of lime. When used for roads this variety compacts very readily and forms an even and hard surface. Steel-furnace slag dust has a high cementing power.

Coal-slack roads.

Coal-slack is sometimes used for road building where neither stone nor gravel is obtainable at reasonable cost. The slack is friable and easily grinds to powder, but makes a fair road for light traffic. In many localities, where there are quantities of slack, it could be profitably spread upon the roads, and being light, the haulage is easy.

The clinkers produced by burning street sweepings and

Fig. 249.—Road Foundation of Oyster Shells.

garbage and the *débris* produced in the manufacture of gas, consisting of the clinkers, old retorts, fire-bricks, ash-pan and coke refuse, have all been tried for paving both footpaths and carriageways, with some satisfaction in the former, but in the latter with failure. The materials are prepared by crushing to a size of about one inch; the crushed material is then screened, and the portion that will not pass through a ¼-inch screen is used for the top finish, and the coarser portion for the foundation. The materials so separated are mixed with either Portland cement or coal-tar, and laid in place in the usual manner, or they may be formed into blocks at a factory and shipped to the place of use.

Clinkers.

In several cities where crematories are employed for the destruction of the garbage, etc., the clinker therefrom is used for making concrete slabs. The clinker is ground very fine, and mixed with Portland cement. The mass of clinker and cement is then passed through a hydraulic press and formed into slabs 2 inches in thickness, and are used for footpath paving under the name of "Destructor" concrete.

Destructor concrete.

Around the Chesapeake Bay and the Gulf of Mexico, oyster shells have been used to a considerable extent to make roads for light traffic. They are spread loosely over the road and speedily become consolidated by the traffic. The shells have a high cementing power but a very low resistance to crushing, and while they make a smooth road surface, it is soon ground to powder, producing a disagreeable dust, and requiring the constant application of new shells to keep it from rutting.

Shell roads.

Pavements made from granulated cork mixed with asphalt and other cohesive substances have been employed in London and other European cities to deaden the noise in the neighborhood of hospitals and churches. The ingredients are compressed into blocks measuring $9 \times 4\frac{1}{2} \times 2$ inches, which are imbedded in tar and rest upon a concrete foundation 6 inches thick.

Cork.

It is claimed that as a paving material it is non-absorbent.

non-slippery, practically noiseless, more durable than wood, perfectly sanitary, and not subject to expansion and contraction. Blocks which have been under traffic for a number of years have given very satisfactory results.

Copper slag.

Paving-bricks are made in Germany from copper slag. The slag is run into heated cast-iron moulds having a capacity of thirty-six bricks; immediately after filling, the moulds and their contents are thickly covered with sand and allowed to stand undisturbed for seventy-two hours. When thoroughly cooled each brick is struck a strong blow with a hammer, and those containing blow-holes crack.

India rubber.

Vulcanized india rubber in large sheets of about one inch in thickness has been used in some European cities, with excellent satisfation. It is laid on a concrete foundation, finished to a smooth bed, on which the sheets of rubber are laid and held in place by strips of iron. It has met nearly all the requirements of a perfect paving material, being exceedingly durable, not slippery, absolutely noiseless and impervious, but its cost prohibits its more general use.

Rubber has been used in London on two roadways passing under the hotel of the Euston terminal station of the London & Northwestern Ry. This was laid in 1881 at a cost of $5.60 per square yard for concrete foundation and $27.10 per square yard for the rubber paving, 2 inches thick. In 1902 the thickness had been reduced by wear to $\frac{5}{8}$-inch in some places and 1 to $1\frac{1}{4}$ inches at others. Bids for new rubber paving in that year were from $27.00 to $86.22 per square yard.

Artificial paving stones.

Artificial paving stones are manufactured in Germany from a mixture of coal-tar, sulphur, chlorate of lime, glass, or furnace slag, by mixing the tar and sulphur at a moderate temperature and adding the chlorate of lime. This mixture is allowed to cool, then is broken into small fragments and mixed with fragments of glass or blast-furnace slag. It is then heated to a moderate temperature, placed in moulds of the desired form, and subjected to a pressure of about 3000 pounds per square inch.

The advantages claimed for this material are: durability equal to that of many stone roads; resistance to changes of temperature; a roughness of surface which gives horses a good foothold; non-transmission of sound; facility of cleaning on account of the closeness of the joints.

A roadway for heavy automobile traffic, used extensively

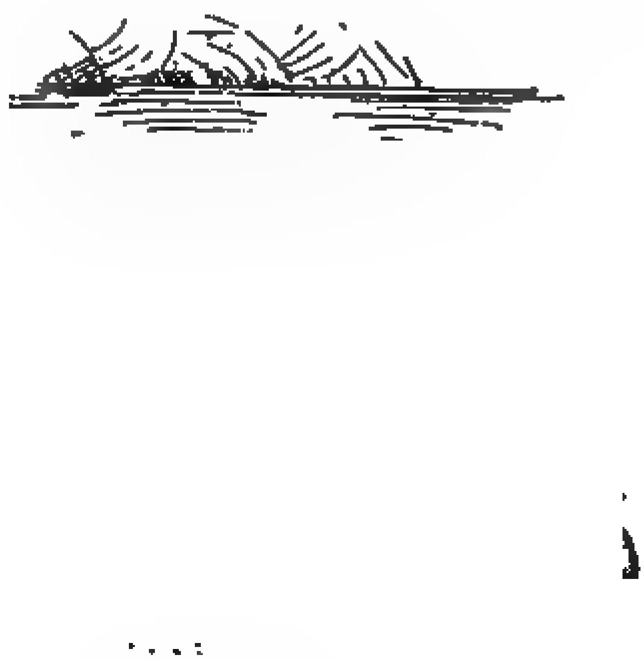


FIG. 250.—Pavement known as "Durax."

"Durax" roads.

in England and Germany is called "Durax." It is made of 3-inch irregular cubes of hard stone, laid in small segments of circles. The stones are cut by machinery, and are comparatively inexpensive, and are laid without grout. It is cheap, almost as smooth as macadam, comparatively noiseless, affords an excellent foothold for horses, and is very durable.

(Courtesy of "Popular Mechanics")

FIG. 251.—View of Country Road, showing Fence, Culvert and Paved Gutter.

CHAPTER XXII

THE ROADSIDE

No matter how smooth and well constructed the travelled way may be, if the roadsides are not cared for, the road, as a whole, will not give a good impression. All rubbish should be removed and the excavations and embankments smoothed and planted with grass wherever it will grow. (See Fig. 22.) Unsightly brush should be cut and grubbed out. Sometimes, however, the brush and the small trees, if suitably trimmed, add to the attractiveness of the roadside.

Hedges and Fences.

Air and sunshine are necessary for the preservation of roads in good order; water and want of light are among the most destructive agents in nature, and no road can be kept in order which is always in a damp state and on which the sun never shines. Everything, therefore that prevents a perfect circulation and distribution of the air and obstructs the revivifying effects of sunshine is to be avoided.

Considered from a purely engineering point of view, there is no doubt that a road would be all the better without hedges and fences of any kind, but inasmuch as a barrier of some kind or other between roads and the adjoining fields is absolutely necessary on other grounds, e.g., to keep cattle from straying from one to the other, to mark the limits of property, etc., a hedge may be considered a necessary evil, and the point for the consideration of the engineer is how to minimize the evil. The higher and thicker the hedge the more obstruction must it offer to the sun and wind. The object to be borne in mind should be to erect such a barrier that (1) shall allow the greatest amount of light and air to pass through it, and (2) shall best answer the non-engineering purposes for which it is required.

According to these principles the best barrier would be one of iron, or of iron and wood combined, provided that it was sufficiently strong to resist being broken down by cattle, horses, etc. Iron wire should not be used, as it is easily bent out of shape, and cattle and horses are very apt to injure themselves in attempting to jump over the fence or to force themselves through it, while barbed wire is still more objectionable.

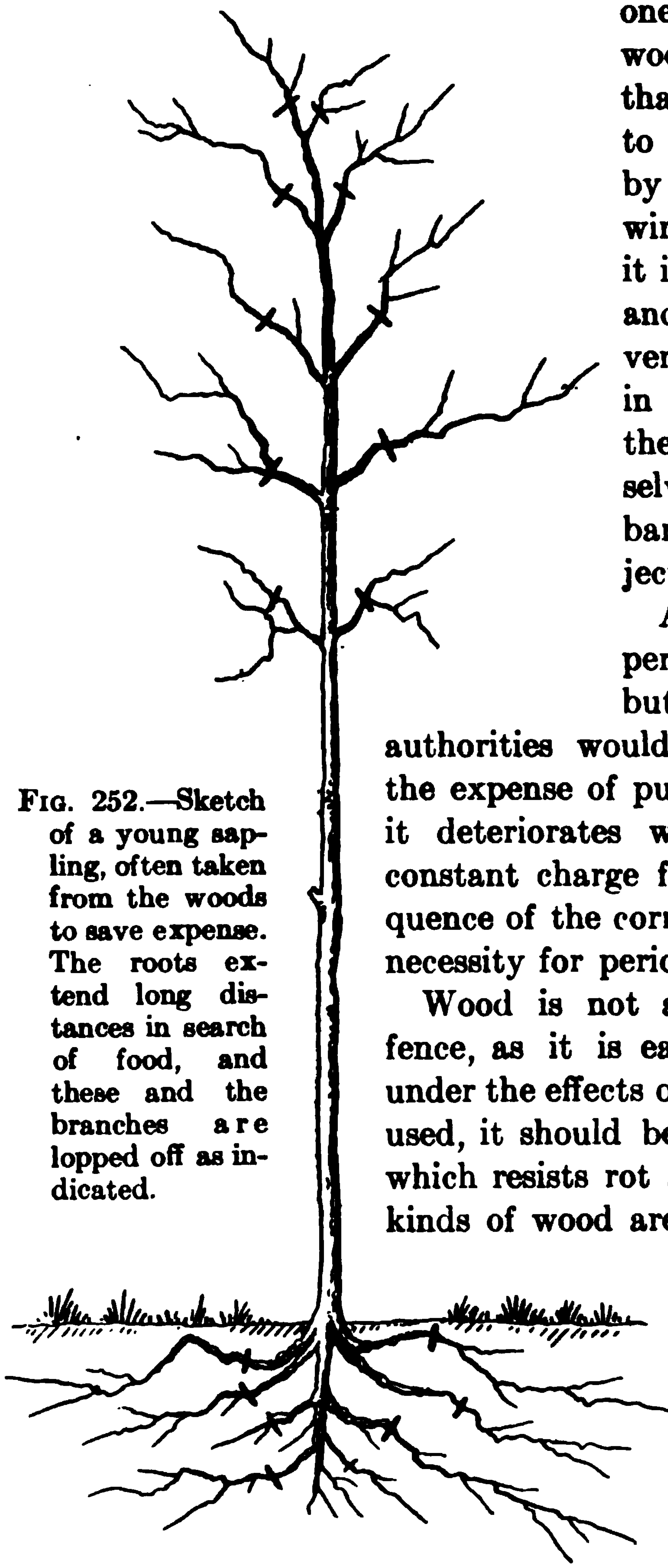


FIG. 252.—Sketch of a young sapling, often taken from the woods to save expense. The roots extend long distances in search of food, and these and the branches are lopped off as indicated.

A strong iron fence forms, perhaps, the best barrier, but it is costly, and few authorities would be prepared to go to the expense of putting it up, especially as it deteriorates with time and entails a constant charge for maintenance in consequence of the corrosion of the iron and the necessity for periodically painting it.

Wood is not a suitable material for a fence, as it is easily destroyed and rots under the effects of the atmosphere; but, if used, it should be oak or some other kind which resists rot as long as possible. Most kinds of wood are perfectly useless for the purpose.

The commonest fence in England is the hedge, and its almost universal use is perhaps due to the fact that it is cheap and requires no skilled

labor to maintain, but a good hedge cannot be established without care in planting and constant subsequent watchfulness.

One of the first engineers who drew attention to the importance of hedges in connection with roads was John Walker, who said:

> "The fences on each side form a very material and important subject with regard to the perfection of roads; they should in no instance be more than 5 feet in height above the center of the road, and all trees which stand within 20 yards of it ought to be removed. I am sure that 20 per cent of the expense of improving and repairing roads is incurred by the improper state of the fences and trees along the side of it, on the sunny side more particularly. This must be evident to any person who will notice the state of a road which is much shaded by high fences and trees, compared to the other parts of the road which are exposed to the sun and air. My observations with regard to fences and trees apply when the road is on the same level as the adjacent field; but in many cases on the most frequented roads in England more stuff has been removed from time to time than was put on; the surface of the road is consequently sunk into a trough or channel from 3 to 6 feet below the surface of the fields on each side. Here all attempts at drainage or even common repairs seem to be quite out of the question; and by much the most judicious and economical mode will be to remove the whole road into the field which is on the sunny side of it."

Mr. Law, in his work on "Roads," make some very useful observations:

> "Few persons are aware of the extent to which a road may be injured by high hedges or lines of trees. Trees are worse than hedges, because they not only deprive the road of the action of the air and sun, but they further injure it by the dripping of rain from their leaves, as a consequence of which the road is kept in a wet state long after it would otherwise have become dry.
>
> "When fences are indispensable they should be placed as far as may be from the sides of the road, and should be kept as low as possible. When there is a deep ditch on either side of the road it becomes necessary, to prevent accident, that the fence should be placed between the road and the ditch,

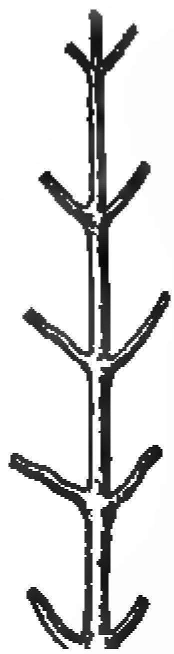


FIG. 253.—Type of the "Undesirable Citizen."

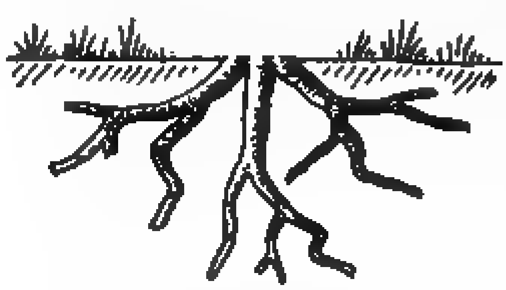
This represents two kinds of trees—often imposed upon innocent customers; one kind, an overgrown nursery tree, passed over for some defect and generally sold cheaply—after being "prepared" as shown. It is first cut back so that the tall, rambling top may not overdraw on the impaired vitality of the mangled roots—which have been cut off near the trunk to save the excavation and cost of caring for full roots. The other kind is a young sapling taken from the woods—overgrown and cut back, and the roots greatly extended in search of sustenance, are cut off, with the effect noted.

but in other situations the fence should be placed on the field side of the ditch. In so doing the surface draining of the road into the side ditches is less interfered with and the action of air and sunshine is less obstructed by the fence.

"The different descriptions of fence which may be employed are various. In districts where stone is plentiful, and especially in the immediate neighborhood of quarries, where stone rubble can be obtained at a trifling cost, dry rubble walls, without any mortar, are very good and cheap and require little or no repair.

"For the road itself, an open post-and-rail fence is the best which can be employed, because it scarcely impedes the action of the wind and the sun upon the surface of the road, but the great practical objection to timber fences is their liability to decay, which occasions frequent and constant expense for renewal.

"The most common, and, all things considered, the most useful fence is the quickset hedge. If properly planted and carefully attended to for the first few years, a natural fence may be obtained sufficiently strong to resist the efforts of cattle to break through, and very economical in cost for maintenance. A bank or mound of earth at least 2 feet in depth should be



THIS TREE CAN NEVER GROW A NATURAL CHARACTERISTIC TOP, AND WILL DISCLOSE MANY DEFECTS IN DEVELOPMENT.

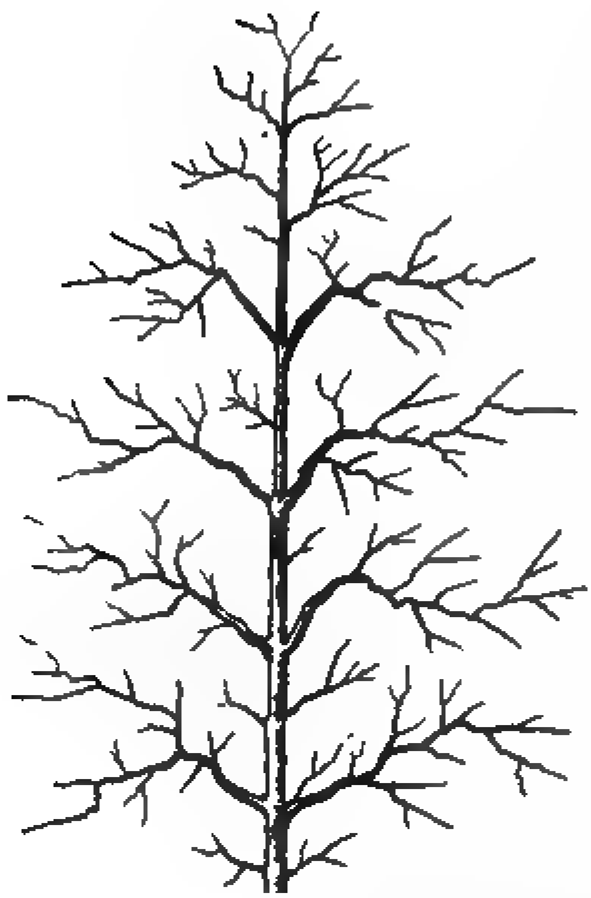
prepared for the reception of the quicks, which should be three years' plants which have been transplanted two years. The best kind of soil is one of a light sandy nature admitting sufficient moisture to nourish the plants and retaining moisture in dry seasons. Heavy clay soils are not sufficiently pervious to water, and plants placed in such soils are never found to thrive. A mixture of rotten leaves is of great use and causes the plants to grow with much vigor. The quicks are most commonly planted in a single row, at distances of about 4 inches apart. But a much better hedge is formed by planting them 6 inches apart in a double row, as shown below, with a space of 6 inches between the rows,

O O O O O O O
O O O O O O

and so arranged that the plants in one row are opposite the spaces in the other. By this arrangement, although the plants are really not so crowded, and have more space around their roots from which to derive nourishment than in a single row, they form a thicker hedge. The proper time for planting quicks is during the autumn or the spring, and, in fine seasons, the operation may be continued during the whole winter. A temporary fence should be put up to protect the young plants from injury, and the fence should be retained until the hedge has attained sufficient strength to require its protection no longer—a period, under favorable circumstances, of three or four years after the quicks are planted. That the plants may thrive they must be carefully attended to at first, and it is essential that they should be properly cleaned and weeded at least twice every year. Once every year toward the end of the summer the hedge should be judiciously trimmed, not to such an extent as to produce stunted plants, but by merely cutting off the upper and more straggling shoots, so as to bring it to a level and even surface. By proceeding in this manner, a neat, strong, and compact hedge of healthy plants will be obtained in about three years after planting."

Trees.

Trees, however much they may add to the picturesqueness of a road, add still more to the difficulty of keeping it in repair; and thick avenues, i.e., trees planted close to each other on both sides of a road, are quite incompatible with the due preservation of the surface. The evil is worse the narrower the road is, for then very little sunshine can get to the road at all, so that the macadam is constantly damp and wears away much more rapidly under traffic.



"As to the desirability of trees on roads and streets, some claim that they do more harm than good; that they impede the circulation of the air, and that, as for the shade they afford, people who do not like sunshine have only to keep on the shady side of the way; that they deprive the road surface of the drying action of the sun and air, and that in wet weather the constant dropping of water from their branches keeps the road in a muddy state. Others claim that trees, especially in streets, temper the heat and serve as a protection against dust, that the evaporation from their leaves tends to keep the surrounding air cool and moist; that the perpetual vibration of their foliage and swaying of their branches, whilst admitting a sufficient amount of light, serve to protect the eyes from the noonday glare; that they act as disinfectants by drawing up and absorbing the organic matters contained in the filth from which the streets of a town are never free and which, infiltrating the ground, are a frequent cause of fevers and infection; and it is asserted that on soil roads some varieties of trees both drain the road and help to hold its earthen surface together by their root fibers." *

Specification for Street Tree.

The tree shall be a nursery-grown tree — sound, straight stem — clear 7-8 ft with well-balanced natural grown head on top; roots full — compact and fibrous. Such roots afford the greatest amount of feeding function. Pruning and in cutting—defer till planting, and afterwards — when under proper hands, its natural form, etc., may be assured.

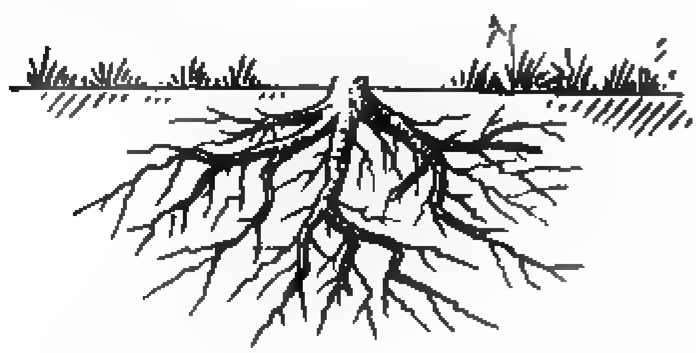


FIG 254 —SKETCH OF TYPE OF DESIRABLE GENERAL CHARACTERISTICS OF A YOUNG TREE 2½ to 3 in. in diam.

All trees that are ornamental, or that have

* Byrne's "Treatise on Highway Construction," p. 727.

value as shade trees, should be preserved and protected, unless they grow so closely that they make too dense a shade. In hot, dry climates, particularly, and, indeed, in most places, trees are a considerable factor in reducing the cost of maintenance, since they lessen the evaporation of the moisture from the macadam. In exposed places where the sweep of the wind would be otherwise unbroken, they serve to prevent in a measure the blowing away of the binder from the road surface. Unfortunately, in such places it is often difficult to make trees grow.

Care in the selection of the kinds of trees best suited to the locality is important. In Massachusetts, sugar, Norway and white maples and American elms have been set out to a considerable extent along the state roads with satisfactory results. These trees grow fast and at the same time are fairly long lived.

Trees should be selected with reference to the climate, locality, quality of soil, extent of space, and circumstances of surroundings in general.

Selection of trees.

Large-growing varieties should be selected for places of great extent, smaller varieties for places of less extent. A low compact tree is not suitable for street planting.

The qualities necessary in a good street tree are that it must be hardy, must not be affected by a long-continued drought, heat must not wither it nor make it look rusty; it must be able to withstand dust, smoke, soot, foul air, and the insidious attacks of insects, and be able to recover from any malicious or accidental injury it may receive.

The tree must be of rapid growth and develop a straight, clean, stem with shady foliage. It must be graceful either in full leaf or when bare, as in winter; its roots must not require too much room, and they must be able to withstand the effects of pollution or rough treatment.

Whatever variety of tree is selected, the following precautions should be taken to insure its flourishing:

1. The young tree should have been well nourished in the nursery; it should not be planted on the street until its stem

is over 8 feet in height and about 3 inches in diameter. The stem should be clean and straight, and the whole tree symmetrical.

2. The ground where a tree is to be set should be suitable for tree growth. If it is not, all poor material should be removed and good soil substituted. The amount to be removed depends upon circumstances and can be determined by examination. A tree to flourish must have plenty of good ground in which to grow; it should be good to the depth of at least 3 feet, and an equal distance in all directions from the trunk when practicable. The amount of good soil is of greater importance than the shape it is in. The further the tree is planted from the curb the better, so as not only to give it a larger body of soil, but to lessen the risk of killing the tree by the pollution of the ground with gas from defective pipes and also excess of moisture from the gutters.

Planting.

Trees should be placed so far from one another that at maturity they will not meet. Such distances will enable them to develop in their natural beauty. To determine the proper distance apart measure the spread of full-grown trees of the same variety as those to be planted; it will vary from 30 to 50 feet. The trees should alternate on opposite sides of the street. Where streets cross at right angles or nearly so, two trees of large-growing varieties may be placed on each corner, far enough from the corner of the curb not to interfere with the catch-basin when there is one. Each tree should be placed on the tree line of one street and the fence line of the other; this will require eight trees to every intersection. The trees so planted should form a handsome mass of foliage and afford an agreeable shade where most needed. At some intersections it may not be possible to plant all the eight trees, but as many as can should be placed. Each tree should be protected with a light iron railing to prevent damage to the trunk from cutting or otherwise.

A good arrangement along roadsides for trees with large tops is to set them about 50 feet apart on each side, but alternated so that there be a tree for every 25 feet along the road.

The Tree-planting Association of New York * has endeavored to interest property owners to plant street trees in the city streets, etc., and, despite lack of coöperation on the part of the city authorities, it has had some success. Several years ago the Tree-planting Law passed the legislature, by which the control of street planting and the care of existing trees outside of the parks, was placed under the park commissioner. The conditions prescribed by the park department under which tree planting must be carried on in the city embody many restrictions which tend to discourage the enterprising property owner in the work of adorning and improving his own property and benefiting his neighbor and the public at the same time.

Tree-planting Association.

City trees in New York are limited in varieties by the park department to the maples, the elms, the planes, the lindens—pin oak mainly. The poplars (the Cardicia poplar in some respects quite desirable) are interdicted. Of the maples, the Norway, sugar, white, scarlet, etc.; of the elm, the English, American (most graceful of tree form), the Dutch, the Huntingdon; of the lindens, the American or European, etc. The Cardicia poplar is a lusty, quick grower with clear bright foliage seldom afflicted with insects, but ages early and the wood is brittle. Trees like the sugar maple, the American elms, the plane, require the wider roadways, as too much incutting spoils characteristic growth of the larger trees. In the city, one of the requirements as to pit is almost prohibitory, namely, soil equal to 3 cubic yards. It is difficult to provide such an excavation in many places and with the necessary soil, and the usual opening in the flagging or concrete walk of a round or square space, brings up the cost of the tree, the planting, and the ground to between from $22 to $30.

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* Secretary, Joseph L. Delafield, 35 Nassau Street, New York City.

APPENDIX I

SPECIFICATIONS AND CONTRACTS *

Between the individual or corporation desiring the work done and the contractor who performs it, stands the engineer who has designed it and who usually superintends its execution. He is in the employ of the persons promoting the enterprise, and it devolves upon him to make sure that those who retain him receive an honest and fair return for their money.

In order that the contractor may understand the scope of the work to be performed and the details of its construction, written descriptions and plans more or less complete, defining the methods of construction, material, etc., to be used, are prepared by the engineer for the approval of the company having the work done and for the guidance of the contractor. These written documents are the Specifications, and together with the Contract, of which they form a part, they fix definitely the relations that shall subsist between the company or corporation and the contractor.

No matter how simple a structure may be, there must be a plan, if it is to be constructed intelligently and efficiently. As the size and importance of the structure increase, the plan becomes more and more complex, and hence the greater necessity for putting it in some fixed and definite form which conveys the exact idea existing in the mind of the engineer. To secure the proper execution of the work of any magnitude, specifications are absolutely necessary, and they should be prepared with great care and exactness.†

Theoretically, three general classes of engineering specifications may be noted. In the first the aim of the engineer is to specify the end or result that it is desired to secure, leaving the contractor free to originate and follow the methods by which these results are to be attained. In the second the engineer aims to secure the desired end, by specifying in

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* Condensed from Waddell and Wait's "Specifications and Contracts," and Whinery's "Specifications for Roads, Streets, and Pavements."

† In addition to their value as memoranda and aids in preparing specifications for a particular project, carefully prepared general specifications, embodying the latest approved practice, sometimes supply the must useful and acceptable brief treatises upon any particular branch of engineering work.

detail the materials and the methods which in his opinion will accomplish the purpose, he himself assuming responsibility for the results. Either of these two classes of specifications is permissible, and the engineer may choose the one which in his opinion seems best adapted to the character of the work to be done, and the conditions under which it must be prosecuted.

In the third class of specifications, met with more frequently than they should be, the engineer undertakes to prescribe not only the character of the materials to be used and the methods to be pursued, but also the results to be attained. The position thus assumed is illogical, and often unreasonable, and may lead to complications between the engineer and the contractor. If a contractor be required to turn out a product which shall conform to certain standards, he may properly be given much, if not full, latitude, as to how the stipulated results shall be secured, and may be held fully responsible for the outcome; if on the other hand the engineer chooses to specify with more or less minuteness the character of the materials to be used and the methods of construction to be followed, and enforces compliance therewith, it seems fair and just that he should assume responsibility for the results produced, and therefore unfair to hold the contractor to responsibility for consequences arising from the use of materials and methods which he was allowed no choice or latitude in selecting.

In street paving work, of well known and standard character, the second class of specifications seems preferable for a number of reasons, the leading one being that the time required to develop the good or bad quality of the work must usually exend over a considerable number of years, and the conditions to which the pavement may be subjected in the meantime are likely to vary so widely that it may be very difficult, if not impossible, to prescribe a satisfactory standard of service and endurance. Disputes are therefore liable to arise between the municipality and the contractor as to the latter's liability, or conditions may make it difficult or impossible to hold the contractor to strict account for that liability.

For convenience of reference and for clearness, specifications are usually divided into clauses, which may be classed as "general" and "specific." General clauses refer to the business relations that shall exist between the parties to the contract. In them is found the general description of the work as a whole without any particular reference to details. Times and methods of making payments, adherence to specifications, inspection, and other analogous headings make up their subject matter. They should be comprehensive in their scope, and should not contradict one another. It is well to avoid a double description of any particular thing, as contradictory clauses are sure to be a stumbling block that will create friction and cause delay. At first glance one would say that such clauses are easily eliminated, but care is necessary to accomplish this.

Specific clauses have to do with the details of construction and the description of the particular features of design. They embody the special ideas that the engineer wishes to incorporate in the work, and they should be just as minute in detail as is requisite to set forth the exact plan desired. Detailed drawings may be necessary to indicate clearly just what is to be done, and these drawings either should be prepared before the specifications are written, or at least should be sufficiently matured in the mind of the engineer to enable him to write his specifications in accordance with them.

The ideal specification is one that furnishes a wholly sufficient guide to the accomplishment of the desired purpose; that provides for every possible contingency which may arise, and is couched in language which not only means exactly what it was intended to mean, but is incapable of any other interpretation. It is needless to say, however, that no example of such a specification can be instanced as a model, as the engineer is, in common with all men, fallible, and he can hardly hope, in the preparation of specifications, to make them perfect; to cover every item and particular; or to escape some ambiguities of expression, and some degree of indefiniteness.

Specifications should look to the accomplishment of an end rather than to the means of its attainment, and it must be remembered that under these circumstances the contractor cannot be held responsible for the mistake of the engineer.

The specifications form a part of the contract, and when the latter is signed, the contractor agrees to all the conditions they set forth. It is proper to assume that he has read the specifications and is familiar with their requirements, and he signs the contract and makes his bond with the full knowledge of what is before him.

The dividing line between the specifications and contracts is most difficult to draw, for in any particular case two engineers will rarely agree as to what clauses pertain properly to the specifications and what to the contract. The preference is to throw as much of the matter as possible into the specifications and reduce the size of the contract proper to a minimum, avoiding repetition of statement in the two parts of the work, but of necessity treating certain subjects in both parts, though from different point of view. All clauses that relate to methods of construction, qualities of materials, character of the work, rules limiting the functions and powers of the contractor and defining the authority of the engineer, directions to bidders, and transportation of men and materials, unquestionably belong to the specifications; alterations of plans, damages, extras, payments, responsibility for accidents, the spirit of the specifications, strictness of inspection, liquidated damages, scope of the contract, and time of completion might perhaps be properly inserted in either division, but it is customary to include all of these clauses and others of like character and scope, in the specifications.

The following general clauses and enumeration of specific clauses, will give an idea of the ground covered by a thorough set of specifications:*

For Grading and Paving, or Repaving

with .... Pavement.
on a .... Foundation, the Roadway
of ....
Street, from ....
to ....
together with all work incidental thereto.

General Description of Work. The work embraced in and to be done under this contract consists of grading the entire street from curb to curb between the limits named, including the removal or readjustment of the pavement now on the roadway, setting and resetting curbing, laying or relaying sidewalks where required, furnishing all new material and performing all the labor required for paving the roadway, together with all incidental work necessary to complete the whole in a proper manner, in accordance with the contract, the plans on file in the office of the city engineer, these specifications and the instructions of the city engineer, herein referred to as the engineer, or his authorized agents.

References. The numbered divisions of these specifications are herein designated as "sections," each being referred to by the number standing at its beginning.

The plans and drawings relating to this work, on file in the office of the city engineer are designated as ....
....

Authority. 1. Wherever, in these specifications, the words, the City are used, they shall be understood to refer to the duly constituted municipal government of the city of ....
or its authorized agents, acting within the authority specifically conferred upon them by the said municipal government.†

Wherever, in these specifications, the words, the engineer, shall be used, they shall be understood to refer to the city engineer of said city, or his deputies or assistants acting within the authority conferred upon them by the city engineer.

But no agent of the city shall have power to revoke, alter, enlarge or relax the stipulations or requirements of these specifications, except in so far as such authority may be specifically conferred in or by the specifications themselves, without the formal authorization so to do, conferred by ordinance, resolution or other usual official action of the city.‡

Interpretation. 2. In case of any actual or alleged disagreement or discrepancy between the contract, these specifications, and the plans for the work on file in the office of the engineer, the language and provisions of the contract shall take precedence and prevail; and the engineer

* From "General Specifications for Roads, Streets, and Pavements," by S. Whinery, 1907.

† In specifications to be used in any particular city the official name of the city government, as the City Council, the Commissioners of Public Works, etc., should be used instead of this general designation.

‡ Such a proviso as this seems proper in justice to both the city engineer and the contractor; the former should not be held repsonsible for the acts of his assistants when they should transcend the authority conferred upon them, and the latter should be put upon his guard with reference to requirements which he is not satisfied are sanctioned or approved by the city engineer.

shall determine in each case whether the specifications or the plans shall be followed.

QUALITY OF MATERIAL AND WORK. 3. The judgment and decision of the engineer as to whether the materials supplied and the work done under this contract comply with the requirements of these specifications, shall be conclusive and final. No material shall be used in the work until it has been examined and approved by the engineer, or his authorized agents. All rejected material must be promptly removed from the work and replaced with that which is acceptable to the engineer, and all improper or defective work must be corrected, and, if necessary, removed and reconstructed so as to comply with these specifications and the instructions of the engineer.

INSPECTION. 4. The engineer may provide for the inspection, by assistants and inspectors under his direction, of all materials used and all work done under this contract. Such inspection may extend to all or any part of the work, and to the preparation or manufacture of materials to be used, whether within the limits of the work on the street, or at any other place. The engineer and his inspectors shall have free access to all parts of the work, including mines, quarries, manufactories, or other places where any part of the materials to be used is procured, manufactured or prepared. The contractor shall furnish the engineer all information relating to the work and the material therefor which the engineer may deem necessary or pertinent, and with such samples of materials as may be required. The contractor shall, at his expense, supply inspectors with such labor and assistance as may be necessary in the handling of materials for proper inspection. Inspectors shall have authority to reject defective material and to suspend any work that is being improperly done, subject to the final decision of the engineer. Inspectors shall have no authority to permit deviations from, or to relax any of the provisions of these specifications without the written permission or instruction of the engineer; nor to delay the contractor by failure to inspect materials and work with reasonable promptness.

The payment of any compensation, whatever may be its character or form, or the giving of any gratuity, or the granting of any valuable favor, by the contractor to any inspector, directly or indirectly, is strictly prohibited, and any such act on the part of the contractor will constitute a violation of these specifications.*

INJURIES TO PERSONS AND PROPERTY. 5. The contractor shall be held alone responsible for all injuries to persons, and for all damages to the property of the city or others, caused by or resulting from the negligence of himself, his employees or agents, during the progress of, or connected with the prosecution of the work, whether within the limits of the work, or elsewhere. He must restore all injured property, including sidewalks, curbing, sodding, pipes, conduits, sewers and other public or private property to a condition as good as it was when he entered upon the work.

SANITARY CONVENIENCES; NUISANCES. 6. The contractor shall pro-

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* It may be objected that this requirement is unusual and unnecessary, since such practices are recognized as wrong, and as presumptive of fraud and malpractice on the part of both of the contractor and the inspector. It cannot, however, be denied that in many cities such means are employed by contractors to unduly inflence the action of inspectors and that not infrequently the latter not only accept, but persistently demand, valuable considerations from the contractor. Silence of the specifications on this point cannot, of course, be construed into consent, but there is no good reason for the silence. There should be left no excuse for misconception of the position of the city or of the engineer upon this point.

vide all necessary privy accommodations for the use of his employees on the street, and shall maintain the same in a clean and sanitary condition. He shall not create nor permit any nuisance to the public or to residents in the vicinity of the work.

PUBLIC CONVENIENCE. 7. No material, or other obstruction shall be placed within five feet of fire hydrants, which must be at all times readily accessible to the fire department.

During the progress of the work the convenience of the public and of the residents along the street must be provided for as far as practicable. Convenient access to driveways, houses and buildings along the street must be maintained wherever possible. Temporary approaches to and crossings of intersecting streets and sidewalks must be provided and kept in good condition, wherever practicable.

BARRIERS, LIGHTS, WATCHMEN. 8. The contractor shall provide and maintain such fences, barriers, "street closed" signs, red lights, and watchmen as may be necessary to prevent avoidable accidents to residents and to the public.

DISORDERLY EMPLOYEES. 9. Disorderly, intemperate, or incompetent persons must not be employed, retained, or allowed upon the work. Foremen or workmen who neglect or refuse to comply with the instructions of the engineer, shall, at his request, be promptly discharged, and shall not thereafter be re-employed without his consent.

ORDER AND PROGRESS OF DOING WORK. 10. The work under this contract shall be prosecuted at as many different points, at such times, and in such sections along the line of the work, and with such forces as the engineer may from time to time deem necessary, and direct, to secure its completion within the contract time. Not more than one thousand (1,000) linear feet of the street shall be torn up, obstructed or closed to travel at any one time without the written permission of the engineer. Completed portions of the pavement shall be opened to travel as directed by the engineer, but such opening shall not be construed as an acceptance by the City of the work done. Where thus opened to public travel by the direction of the engineer, the contractor will not be held responsible for injuries to the work caused by such travel or public use, pending the final completion and acceptance of the whole work.

MEASUREMENT AND ESTIMATES. 11. Final estimates will be based upon the actual quantities of completed and accepted work, customary or conventional methods of measurement and computation to the contrary notwithstanding.

GRADE AND CONTOUR OF PAVEMENT. 12. Roadway pavements shall be laid to such grades, crown and contour of surface as the plans may show or the engineer may direct, and the surface of the completed pavement shall conform accurately to such grades, crown and contour. The designed surface of the completed pavement shall be considered as the datum or plane of reference in fixing the location or level of the subgrade, of the pavement foundation, and of structures connected therewith. It will be hereafter referred to in these specifications as "the pavement datum."

CITY MONUMENTS OR STAKES. 13. The contractor must carefully protect from disturbance or injury all city monuments, stakes and benchmarks, and shall not excavate nearer than five feet to any of them without the permission of the engineer; or until they have been removed, witnessed, or otherwise disposed of by the engineer.

OLD MATERIAL. 14. All material or structures removed from the street and not required for the new construction, but which the city may desire to reserve, shall be delivered and neatly piled up in a corpora-

tion yard or elsewhere, by the contractor, as the engineer may direct. Such reserved material shall be considered in the custody of the contractor until delivered at the place designated, and he will be held responsible for its care and protection, and must make good any losses occasioned by damage, theft, or misappropriation while it is on the street or en route to the place of storage. If the contractor shall be required to haul such reserved material more than one-half mile, he shall be paid a reasonable price, to be agreed upon in advance, for the haul exceeding that distance.

Material taken from the work which is to be used in the new construction shall be compactly piled where it will least obstruct the sidewalks or adjoining sections of the street, and properly protected by the contractor until it is required for use.

All old material removed from the work, including the material excavated in preparing the sub-grade, not reserved by the city nor to be used again in the work, shall belong to the contractor and must be removed by him from the street as promptly as possible. It must not be placed on the sidewalks or adjacent streets, nor on any other street or property belonging to the city, nor on the property of private owners, without the written consent of the engineer, or the owner of the property.

Storage of New Material. 15. The material for construction when brought upon the street shall be neatly piled so as to cause as little obstruction to travel as possible, and so that it may be conveniently inspected.

Rebuilding and Adjusting Street Structures. 16. Catch basins, manhole, sewer and water frames and covers, sewer inlets, water pipes and other conduits, belonging to the city and within the limits of the work, shall, if necessary, be reset to the new lines and grades of the street and for this purpose good brick masonry of the original thickness, laid in Portland cement mortar shall be used. Great care must be taken to set all such structures as project through the pavement exactly to the grade and contour of the new street surface, and any defects in the conformity of such structures to the pavement datum, discovered at the time, or during the progress of the work, or during the guaranty period, stipulated in Sec. 108,* shall be promptly remedied by the contractor.

Noiseless Manhole Covers. 17. Asphalt-filled noiseless covers, complete, for water and sewer manholes, of approved design, shall be furnished and set by the contractor wherever directed by the engineer. They shall be made according to general plans and details furnished by the engineer, and of such dimensions as to properly fit their frames.

Clean Sidewalks. 18. During the progress of the work, the sidewalks and portions of the street adjoining the work, or in its vicinity, must not be obstructed or littered more than may be absolutely necessary, and the adjacent sidewalks must be kept clean.

Final Cleaning Up. 19. Immediately after the completion of the work or any consecutive portion of it, the contractor shall remove from it all unused material, refuse and dirt placed by him on or in the vicinity of the work, or resulting from its prosecution, and restore the street to a condition as clean as before the work was begun; and the new pavement shall be properly cleaned.

Incidental Work at Contractor's Expense. 20. All the work to be done by the contractor, specified and enumerated in sections 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19, as well as any minor details of work not specifically mentioned in the specifications, but obviously necessary for the proper completion of the work, shall be

* See page 481.

considered as incidental, and as being a part of and included with the work for which prices are named in the contract. The contractor will not be entitled to any extra or additional compensation therefor.

EXTRA WORK. 21. The city may require the contractor to furnish such additional materials and to do such additional work, not provided for in the contract and these specifications, but which may be found necessary or pertinent to the proper prosecution and completion of the work embraced in the contract, at prices to be agreed upon in writing, in advance. But no work other than that included in the contract and these specifications and which is covered by and to be paid for at the prices named in the contract, shall be done by the contractor except upon a written order from the engineer. In the absence of such written order from the engineer the contractor will not be entitled to payment for any such additional or extra work.

CURBING TO BE COMPLETED IN ADVANCE. 22. The setting of all new curbing and guttering and the redressing, resetting or readjustment of all old curbing must be completed at least 100 feet in advance of the construction of the street foundation.

PREPARING THE SUB-GRADE. 23. The whole area to be occupied by the pavement and its foundation shall be excavated to a sub-grade at such a depth that after being compacted by the roller, the surface will be ....inches below the pavement datum, and truly parallel thereto. In excavating, the earth must not be disturbed below the sub-grade. Plowing will not be permitted where the depth of earth to be removed is less than six (6) inches, and in no case must the plow be allowed to penetrate to within less than one inch of the sub-grade. Places that are found to be loose, or soft, or composed of unsuitable material, below sub-grade, must be dug out and refilled with sand, or other material as good as the average of that found on the street. After the excavation is completed and the surface neatly trimmed, the whole area shall be well compacted by rolling with a roller weighing not less than five tons. Areas inaccessible to the roller shall be rammed until they are as well compacted as the rolled surface. When the rolling is completed the surface must be nowhere more than three-fourths inch below, nor more than three-eighths inch above the true sub-grade. If, after the rolling is completed and before the pavement foundation is laid, the surface shall become disturbed in any way, it must be replaced and properly compacted.

Where the natural surface of the ground shall be below the sub-grade, or shall become so by the removal of old pavement or other structures, it must be filled to the sub-grade in layers not exceeding five inches in depth, and each layer shall be thoroughly rolled or rammed before the next layer is placed upon it, and when the filling is completed the filled area must be properly trimmed and compacted by rolling or ramming to the true sub-grade, as in excavation. The material excavated from the street may be used for such filling, provided it be of suitable quality. Where it cannot be thus procured from the street it must be obtained by the contractor elsewhere, in which case the actual quantity so obtained, measured after it is compacted in the street, will be paid for at the contract price for "earth filling." The price bid for "earth excavation" will be paid for all material excavated above the sub-grade, measured in place on the street, which price includes the cost of disposing of the excavated material, whether as waste or filling, and of trimming and rolling or ramming the sub-grade, and of making it ready for the pavement foundation.

Where the soil composing the sub-foundation is found to be wet or "springy," a system of soft tile drains, discharging into the street drainage

system, shall be constructed by the contractor, as directed by the engineer. The tile shall be laid in trenches about one foot wide and from one to two feet deep. After the tile is in place the trenches shall be filled with compacted crushed stone or gravel. The tile will be paid for at the contract prices for the same, which shall include the cost of excavating and filling the trenches.

Then follow specific clauses covering all details in regard to foundations, laying the pavement, etc., according to the special form of structures used.

GUARANTY.* 24. The contractor shall guarantee that all the materials used and all the work done under this contract shall fully comply with the requirements of these specifications, the plans hereinbefore referred to and the instructions of the engineer. Any defects in the completed work, or any part of it, or any failure of the work to fully perform or endure the service for which it was intended, which, in the opinion of the engineer, are attributable to the use of materials, skill, or workmanship not in compliance with the said specifications, plans and instructions, that may appear in the work, or any part of it, within a period of............. years after the date of the certificate of completion and acceptance, shall be regarded as prima facie and conclusive evidence that the contractor has failed to comply with the said specifications, plans and instructions. And the contractor shall, at his own expense, at such time and in such manner as the engineer may direct, repair or take up and reconstruct any such defective work, in full compliance with the original specifications, plans and instructions. And as surety for the performance of this guaranty the contractor's bond, required by the contract, shall remain in full force until the expiration of the period of .... years above stipulated in this section.

The importance of drafting contracts properly cannot well be overestimated. An incorrectly drawn agreement is almost certain to involve serious trouble and often pecuniary loss to an innocent party; hence it behooves the engineer to study thoroughly and fundamentally the science or art of contract writing. But before he can draft a contract, he must have clearly in mind a full and well-defined idea of all the conditions and desiderata, and he should epitomize these systematically before beginning to write. It is advisable to keep constantly in view the possibility that each party to the contract may be unscrupulous and willing to take every possible advantage of every weakness which the contract may contain and which will tend to his own profit.

The essential elements of any contract, according to Mr. John Cassan Wait,† the noted authority, are as follows:

"1. Two parties with capacity to contract.

"2. A lawful consideration—a something in exchange for its legal equivalent, a *quid pro quo*.

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* These specifications are designed to secure the construction of the pavement in a proper manner, the city assuming responsibility for the character and utility of the work. The guaranty here proposed is therefore intended to cover only a proper compliance with the specifications, for which the contractor may properly be held responsible, and not the sufficiency or utility of the work, if constructed according to the specifications. The period of guaranty should therefore be short, not exceeding two years.

† "Engineering and Architectural Jurisprudence."

"3. A lawful subject-matter, whether it be a promise, an act, or a material object.

"4. Mutuality—a mutual assent, a mutual understanding, a meeting of the minds of the parties."

Without these four elements no contract is binding in law. The essentials of a well-drawn contract that comes within the province of the engineer, however, are as follows:

1. A proper and customary form.
2. A full and correct description of all parties to the agreement.
3. A thorough and complete preamble.
4. A statement of when and under what conditions the contract is to become operative.
5. The limit, if any, for duration of contract.
6. An exhaustive statement of what each party to the contract binds himself, his executors, his administrators, successors, or assigns, to do or to refrain from doing.
7. A clearly defined enunciation of the consideration which each party is to receive; this is, the essential *raison d'être* of the instrument.
8. Forcasting of all possible eventualities that would materially affect the agreement, and a full statement of everything that is to be done, in case of each eventuality.
9. Penalties for failure to comply with the various terms of the agreement.
10. Provision for possible cancellation of contract.
11. Provision for settlement of all business relations covered by the contract, or resulting therefrom in case of cancellation, taking into account all possible important eventualities.
12. Mention of the place where the agreement is drawn or the place where it is to be put in force, so as to show the state under the laws of which the validity of the contract is to be determined, should suit be necessary to enforce it.
13. Methods of payments, if any are to be made.
14. Provisions for extra compensation, and the limitations connected therewith.
15. Provision for possible changes in contract.
16. Provision for transfer of the contract, or for subletting.
17. Provision for settlement of disputes.
18. Provision for satisfactory and sufficient bonds, if any be needed.
19. Provision for defense of law suits, if such provision be necessary.
20. Definition of names used in contract, such as "engineer," "company," "contractor," or "trustee."
21. Dating of contract.
22. Proper signature and the necessary seals, if the latter be required.
23. Witnesses to the signatures, or execution before a notary public.

As illustrating these points, the following example of a good typical

contract may be reproduced. This is the standard "Form for Contracts" of Waddell and Harrington, engineers, of Kansas City, Mo., for appending to construction specifications drawn up in their office.

MEMORANDUM OF AGREEMENT, made and signed this..........day of......19.., by and between the..................................
the party of the first part, and sometimes termed in this agreement and in the specifications, the "company," and............................
the party of the second part, and sometimes termed in this agreement and in the specifications the "contractor."

WHEREAS,..
....

NOW THIS AGREEMENT WITNESSETH:

First. The party of the second part, for and in consideration of certain payments to be made to it, as hereinafter specified, will..........
....
all in accordance with the plans and specifications hereunto annexed and made a part hereof, and will fully finish and complete the same by..
unless, in the opinion of the engineer, the party of the second part be delayed or prevented by circumstances that are absolutely beyond his control.

Second. The party of the second part shall begin the work of construction as soon as practicable after the signing of the contract, and shall push the same to completion as rapidly as possible, and within the time limit or limits set in the accompanying specifications.

Third. All important dimensions and characteristics of the structures are fully described in the accompanying drawings and specifications, which form a part of this contract.

Fourth. In consideration of the performance by the party of the second part of its convenants and agreements, as hereinbefore set forth, the party of the first part hereby covenants and agrees to pay to the party of the second part as follows:

....
....
....

In case that there be any other materials furnished by the contractor that are not included in this list, they shall be paid for on the basis of actual cost to the contractor plus ten (10) per cent for his profits.

It is understood that no payments, either partial or final, are to be made for any material which is to be used for false work or plant, but only for such material as is left permanently in the finished construction.

Fifth. The schedule prices to be adopted in making partial payments for all work as it progresses are to be as follows:

....
....
....

Sixth. All material paid for by the party of the first part shall be deemed to be delivered to, and to have become the property of the said first part, but the party of the second part hereby agrees to store it and to become responsible for it during the continuance of this agreement. If any of it be damaged, destroyed, or lost from any cause, including,

among others, floods, washouts, and fires, the contractor shall repair or replace the same at his own expense to the satisfaction of the engineer.

Seventh. In case the party of the first part, notwithstanding the failure of the party of the second part to complete its work within the time specified, shall permit the said second party to proceed, and continue and complete the same, as if such time had not elapsed, such permission shall not be deemed a waiver in any respect, by the first party, of any forfeiture or liability for damages arising from such non-completion of said work within the time specified, and covered by the "Liquidated Damages" clause of the specifications; but such liabilities should be continued in full force against the said second party, as if such permission had not been granted.

Eighth. No change or alteration shall be made in the terms or conditions of this agreement without the consent of both parties hereto in writing, and no claim shall be made or considered for any extra work unless the same shall be authorized and directed in writing by the engineer.

Ninth. In the event of any delay in completing the work embraced in this contract, the party of the second part shall be entitled to no extra compensation on account of such delay, as it is hereby assumed that in submitting its tender it took its chances for the occurrence of such delay. If, however, in the opinion of the engineer, the contractor be delayed by any act of the company to such an extent as to cause him serious hardship, such as temporary cessation of the work, the company shall allow the contractor whatever compensation for such delay as may appear to the engineer to be just and equitable.

Tenth. The party of the second part hereby agrees that it will not assign or sublet the work covered in this contract, or any portion of it, without the written consent of the party of the first part, but will keep the same within its control.

Eleventh. The decision of the engineer shall control as to the interpretation of drawings and specifications during the execution of the work under them; but if either party shall consider itself aggrieved by any decision, it may require the dispute to be finally and conclusively settled by the decision of the three arbitrators, the first to be appointed by the party of the first part, the second by the party of the second part, and the third by the two arbitrators thus chosen. In case that the two first chosen fail to agree upon a third, the latter shall be appointed by...
By the decision of these three arbitrators, or by that of a majority of them, both parties to this agreement shall be finally bound.

Twelfth. As, according to the terms of the accompanying specification, which form a part of this contract, the party of the second part is to indemnify the party of the first part against all liability or damages on account of accidents occasioned by the omission or negligence of itself, its agents or its workmen during the continuance of this agreement, and against all claims for royalties or patents; it is hereby agreed that the party of the second part shall be promptly and duly notified in writing by the party of the first part of the bringing of any such suit or suits, and shall be given the privelege of assuming the sole defence thereof. The party of the second part is to pay all judgments recovered by reason of accidents or patents in any suit or suits against the party of the first part, including all legal costs, court expenses, and other like expenses.

Thirteenth. The contractor further agrees to give the company a surety-company bond, satisfactory to the party of the first part in the

sum of...
for the faithful performance of this contract and the specifications, and of all the terms and conditions therein contained, and for the prompt payment of all materials and labor used in the manufacture and construction of the structures, and to protect and save harmless the company for claims on patents and from all damages to persons or property, caused by the negligence or claim of negligence of the contractor, his agents, servants, or employees in doing the work, or in connection therewith, and from injury to or loss of materials paid for by the company either partially or in full before the completion and acceptance of the construction or constructions.

Fourteenth. The word "Engineer" as used in this contract refers to the Consulting Engineers of the ....
or their duly authorized representative.

IN WITNESS WHEREOF, the parties to this agreement have hereunto set their hands and seals.

Dated the day, month, and year first herein written.

WITNESSED BY

....
....
....
....

APPENDIX II

PAVEMENT GUARANTEES: REASONS FOR SHORTENING OR ABOLISHING THEM *

MANY miles of pavements, although under bonded guaranty for good condition, are in bad order on many streets of many cities. Municipal officials and taxpayers are rapidly realizing that pavements, when first laid, should be properly constructed under the responsible and direct supervision of the city engineering department, and that bonded time guaranties should not be relied upon, but be abolished or at least reduced to the short time needed to enable poor construction to be discovered and replaced. Who would think of having a city hall, water works or other kinds of public works built and rely upon guaranties that these things would be good and durable? Private works are not conducted on a basis of guaranties, but upon qua'ity.

From the point of view of municipalities and property owners, the principal objections to long-time guaranties are as follows:

First. Municipal officials are naturally often careless in awarding contracts when accompanied by bonded time guaranties. They depend on the bond rather than on the reliability and experience of the contractor in the special class of work to be done. They often investigate the quality of the bond instead of the quality of the paving material offered. They fail to have complete specifications and fail to depend principally upon efficient supervision by the city engineer of the materials and work during construction. It is often stated by officials of boards of public works, paving committees, etc., in awarding contracts to persons or companies whose lack of experience is known and the quality of their materials unknown or whose price is suspected of being too low for good work, that "a good surety bond for so and so many years is offered and we can safely rely on that." There are hundreds of poor pavements in our cities built under "good bonds"; but a "good bond" in a city file is not a good pavement on a city street. The time guaranty bond is a very unsatisfactory, slow and uncertain way to convert a poor pavement into a good one. It takes a pavement from the control of the engineering department and puts it for a long period as a burden on the legal department of a city.

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* Abstracted from paper on "Pavement Guarantees: the Use and Abuse," by J. W. Howard, C.E., read before the Board of Trade, Newark, N. J., December, 1907.

Second. Long-time guaranties have very seldom proved efficient for getting poor pavements made good. Nearly every city has many pavements where guaranties have not been complied with. There are but a few instances of recovery by a city of damages under a guaranty bond. Because law is a slow process, the pavements meanwhile become more dilapidated. I speak from an experience of some years during which, aside from other engineering work connected with pavements, I have examined poor pavements and my reports and testimony have helped cities collect damages from defaulting contractors or from bondsmen. The chief engineer of pavements of Chicago in a recent paper showed how slow and unsatisfactory the legal proceedings are, in the cases pending in Chicago for more than three years, to compel contractors or bondsmen to put their pavements in order. Many contractors and all bonding companies have attorneys paid by the year. It is easier and much cheaper for them to prolong litigation than to repair pavements.

Third. The price for a well-constructed pavement, when time guaranty bonds are required, is much increased by reason of the cost of surety company bond premiums, the cost of reserves to cover unforseen liabilities and contingencies, probable lawsuits, political obstruction, which are factors which cannot be ignored by the contractor, and which are included in the price he charges for the pavement. A city and property-holder receives practically no return for these added charges for time guaranties.

Fourth. Incompetent, inexperienced, scheming or politically affiliated contractors sometimes bid low prices to construct pavements without including sufficient to cover the cost of proper repairs and other liabilities of the guaranty. They sometimes deliberately figure on the basis that if the pavement should fail they will be able, in some way, by friendship, political influence or legal process, to avoid the liability of the guaranty, and they often succeed. Cities are too likely to accept such bids. Under the unfortunate laws of some states, cities are required to accept such low, "cheap" bids, although offered in competition with the bids of experienced and conservative contractors, who must bid higher to furnish durable and, in the end, cheaper pavements for the city. In states requiring its cities to award contracts to lowest bidder, it is easy to abolish time guaranties and to provide complete specifications, thorough inspection of construction, and thus quickly eliminate the cheap-poor-work-bidder. It is not good policy nor do cities wish to pay for anything less than cost to the contractors. They are willing to pay a fair profit to contractors for good work.

Fifth. Time guaranties remove from the municipal engineer or officials in direct charge of the work the right to fully direct important details of construction in accordance with their best judgment, either during its first construction or during the period of guaranty. If the engineer exercises his prerogative in directing how any of the details are to be done, the contractor and the bondsmen are thereby often found to be relieved from the guaranty. In a recent decision of the New Orleans

District Court, Shea *v.* New Orleans, to recover money for work alleged by the city to be defective, the court relieved the contractor from his guaranty, because the work was done in accordance with directions of the engineer.

Sixth. A city should not lose complete control of its streets at all times by having the pavements on the surfaces under partial control of private contractors, as they practically are during guaranty periods. No one can foretell the needed uses of the streets, as changes, construction above, below or adjacent to the streets. No such changes, etc., can be made for the benefit of the city or otherwise without, in a measure, the city or property holder losing the asset of repairs of pavements not yet performed during the balance of a guaranty subsequent to the changes, etc., in connection with the street which are needed and accomplished. A city cannot properly control the car-track pavements when they or even the adjacent pavements on a street are under guaranties.

Seventh. It is often illegal to require long-time guaranties in contracts for construction to be paid for by assessment, because the laws require the general repair to pavements due to general use of pavements shall be paid from general funds of the city and forbid such repairs to be assessed as a part of the original charge or otherwise against abutting property. If maintenance guaranty is included in the original contract price, it generally thereby illegally assesses the cost of maintenance on the abutting property.

Eighth. A city whose pavements are well constructed and free from time guaranties can make subsequent repairs due to wear or other causes, either by using its own employees or by taking advantage of new competition which constantly arises. It can avoid being tied up with possible monopolies or being kept from repairing its streets for long periods by having annual repair contracts and paying for the repairs each time they are made. A city thus avoids the heavy bonding and extra indefinite expenses of time guaranties.

Ninth. Many municipal engineers and honest experienced city officers are of the opinion that it is not for the interests of cities to require guaranties beyond such period as will bring out defects due to neglect or accident and that such defects appear within one or two years. It seems now the universal opinion that a contractor shall not be permitted to guarantee a pavement beyond a term of five years, because not economical nor best for a city. It is a well known fact that the largest, most conservative and responsible paving companies charge into the cost of work an extra cost for "reserve for maintenance guaranty," where time guaranties are required in their contracts.

In conclusion, we can feel sure that engineering and legal experience shows that a pavement guaranteed for longer than five years is neither economically nor legally safe or best for city or taxpayer. Two years are sufficient to demonstrate the quality of a pavement laid under inspection of competent men. The best plan for city, taxpayer and all

concerned is a guaranty or an abeyance of final acceptance for two years from the first of June first following the completion of the pavement, June being selected because experience and observation demonstrate that a guaranty should terminate, not in wet or cold winter weather, but in early summer, so that any defects will be fully visible, the pavement easily inspected, the repairs properly made by the contractor and the city receive a good pavement.

APPENDIX III

CONCERNING THE WEAR OF ROADS BY AUTOMOBILES

SEVERAL statements have already been given in Chapter X to demonstrate the fact that high-speed automobiles are injurious to the ordinary road surface, but in these, the cause of the damage is not explained. As an example of this damage "Engineering News" recently published an abstract from a German contemporary showing the result of a concentrated traffic of passenger automobiles upon a short section of highway in Germany.

Unusual circumstances subjected this short stretch of road to very heavy traffic of automobile busses for a period of five months, and in that period some interesting studies of road wear were made. The traffic was much heavier, both in amount and in loading, than normally occurs even on heavily traveled main highways, and the results represent what might be called an accelerated test of road destruction by motor-car traffic. The showing made is rather alarming, but in reality it only puts into specific figures what has been more or less generally recognized as true.

The two groups of cross-sections shown herewith as Figs. 1 and 2 give typical illustrations of how rapidly the traffic cut through the hard surface of the highway. The circumstances of the case were as follows:

A railway tunnel between the towns of Mettlach and Ponten caved in on Nov. 27, 1907; this interrupted the line from Trier to Saarbrücken and necessitated the employment of auxiliary means of transportation to bridge the gap for passengers and baggage. An average of 10 passenger-trains each way per day had to be taken care of.

For a fortnight local vehicles, such as cabs, farm wagons, etc., were employed. On Dec. 6, two closed motor-cars holding 12 to 15 passengers each were obtained. A week later ten large motor-busses belonging to the Grosse Berliner Motor-Omnibus Co., were put into service on the portage and the two smaller busses were dismissed. These ten busses were in service till early in February, when four of them burned, after which the remaining six handled the service.

The tunnel was restored ready for traffic by May 1, 1908, making the period of road portage practically five months. During this time the motor-busses averaged 80 trips between Ponten and Mettlach, though in the Christmas weeks the number of trips was increased to as high as 140 per day.

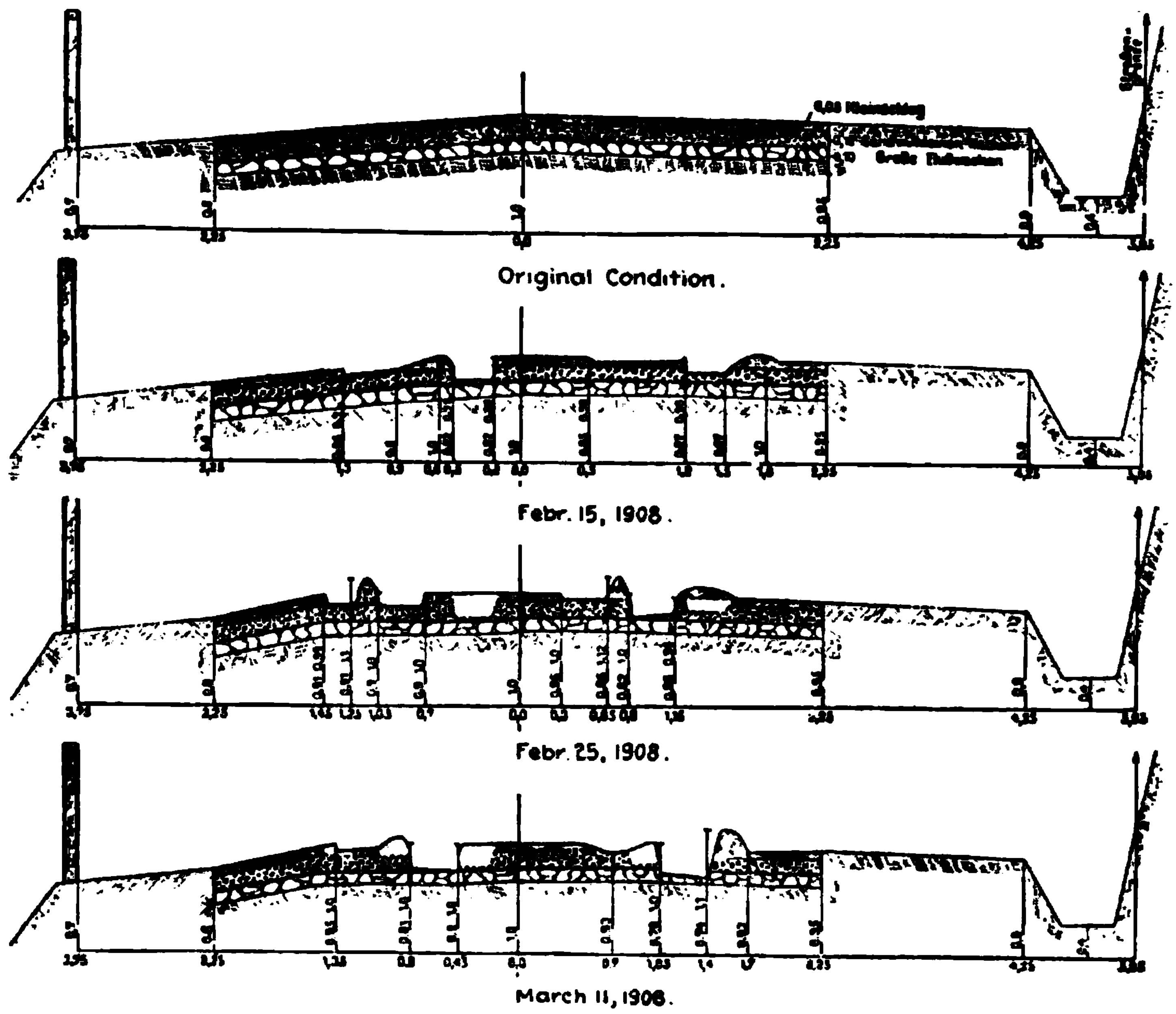

FIG. 1.—A Typical Cross-section of the North Slope.

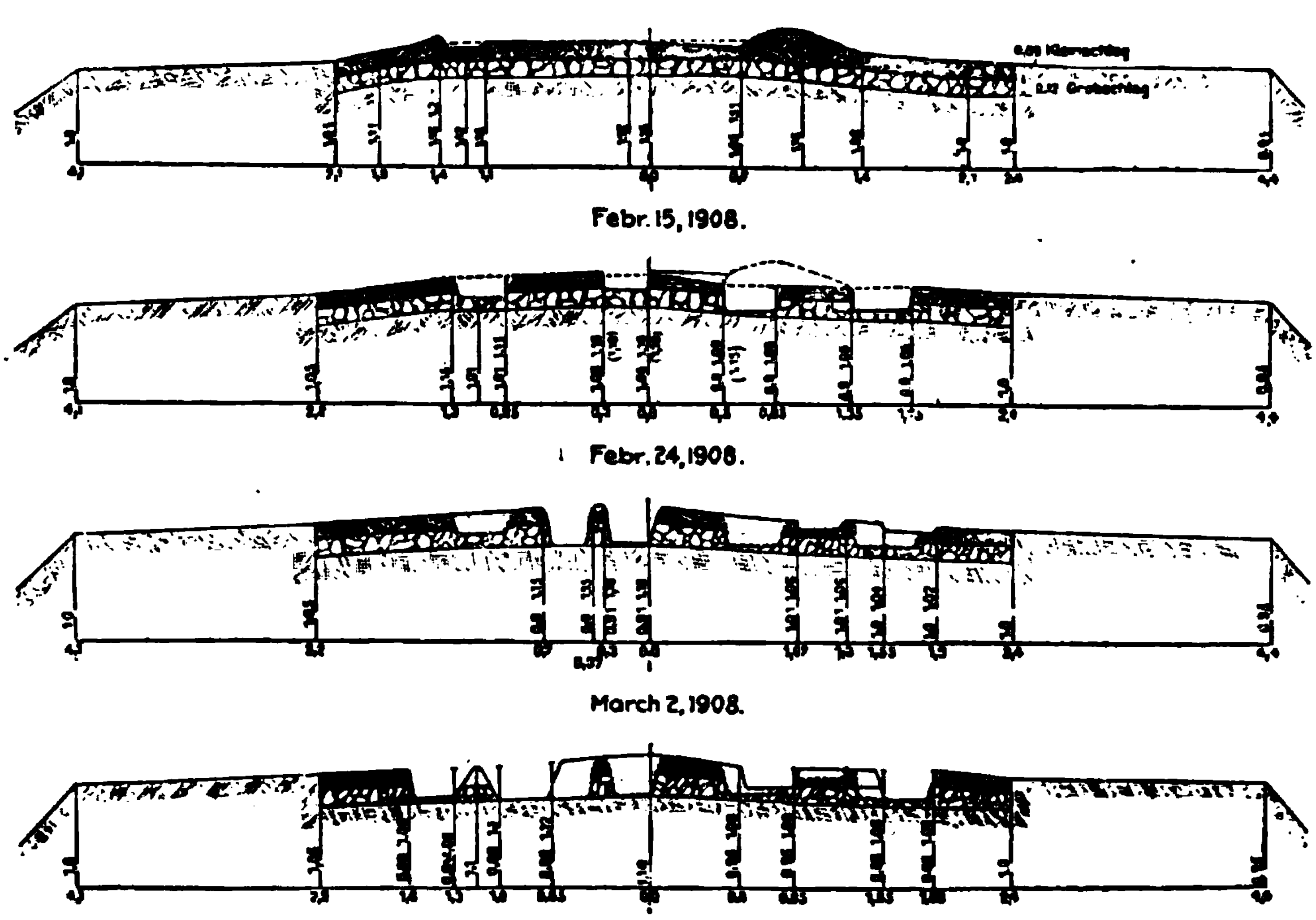

FIG. 2.—A Cross-section on the Upland.

The stretch of road in question, excluding the terminal portions which lay in paved streets, is slightly under two miles long. A short stretch near the middle is level, lying on the ridge through which the railroad tunnels, while the rest is steeply sloped down toward the two ends. The northerly slope averages 6.9 per cent grade, the southerly slope 8 per cent. The road had a broken-stone pavement, generally a kind of Telford, i.e., there was a base course of shingle or cobbles. The upper course consisted of quartzite, stated to be very suitable for road purposes.

Fig. 3.—View of the Rutted Road Surface in Winter.

The age of the road surfacing varied, but the important feature is that the older parts had been kept in careful repair, and the entire two-mile length was in first-class condition.

Perceptible wear began when the large motor-busses came into service. A picking-up action was noticed in the tire tracks, and in a few days the road was covered with fragments of stone torn out of the surfacing. Further, although the gage of the rear wheels was larger than

that of the front wheels, the concentration of wear from tracking soon produced the results shown in the sketches.

These large busses are described as follows: Weight, empty, 13,000 lbs., of which nearly 9,500 lbs. was on the rear axle; capacity, 25 passengers; weight loaded, about 17,000 lbs.; tires, solid rubber, width 4 ins. front, 8½ ins. rear; gauge, 5.9 ft. front, 6.6 ft. rear; speed, 6 to 15 miles per hr.

The rutting of the road once started, it developed in a short time so far as to form grooves up to 6 ins. deep by 12 ins. wide, and ridges formed alongside the ruts from the displaced material. The ruts were not clean but contained much loose material, which the following wheels either pushed aside or crushed.

Repair work was started as soon as the destructive actions were noticed, and was continued to the end of the period. Coarse broken stone was placed in the ruts and pressed down with a steam roller, whereupon a binding course of small stuff such as cinders and coarse sand was similarly applied. This could be done only when the road was not frozen.

Two weeks often sufficed to destroy the repair work completely. During the last three months it was a constant struggle to keep the road in passable condition. If heavy continued rains had occurred in March or April it would have been impossible to maintain the traffic.

The wear and grooving was worse in December. Freezing weather in January and the first part of February held matters stationary and preserved the road, though in badly rutted condition. Thereafter the southerly slope thawed first, and repair work was concentrated on it, the northerly slope being taken up later.

The five-month's maintenance cost about $4,000, or over $2,000 per mile. About 1,250 cu. yds. broken stone and an undetermined amount of sand and cinders were used. Mr. M. Görz, who reports the details, says that but for good weather, a convenient supply of materials and the availability of labor from the railway department it would not have been possible to keep up the road. These favorable factors, we conclude, also operated to reduce the cost.

The influence of the heavy weight concentrations upon the destruction of the road was evident in one of the paved streets at one end of the route. A street newly paved with stone block, but apparently without concrete base, was used temporarily to detour around the main street. But in a few days the surface was deeply grooved, the wheels crushing the stone blocks down into the soil, and the busses had to use another street.

This is a most graphic example of the serious damage done by automobile tires to road surface. Yet, around the suburbs of any of the larger cities we can find almost equally serious examples of wear at any place where automobile traffic is concentrated, particularly where high speeds are possible and around curves.

Commmenting on this, "Engineering News" says:

"A dozen years or so ago, prophecies were common that a golden age for roads and streets would come when horses should be displaced by self-propelled vehicles. The horse, it was claimed, was the chief instrument in the wear of our roads and highways, by digging up the surface with the calks on his shoes. The iron tire of horse-drawn vehicles, too, was referred to as a crushing mill which was continually reducing to powder the material of the roadway surface. 'Only give us vehicles without horses, with the wheel treads fitted with rubber tires,' it was said, 'and the wear on the roads will be reduced practically to nothing.'

"It is interesting to reflect on these ideas so commonly held a dozen years ago, and to compare them with the actual experience with the automobiles of the present day.

"The question may well be asked: why should the theory of a dozen years ago be so far apart from the experience of to-day? Why does the automobile tire, which was expected to produce no wear at all upon roads, actually wear them so terrifically?

"It is worth while studying this question, because when the answer is found it is an excellent illustration of the fact that really theory and practice are not in conflict, as might at first sight appear. The only trouble with the theory of a dozen years ago was that it did not take all the facts into consideration. Hindsight is proverbially better than foresight; and now that we know how badly the automobile wears our road surfaces, it is not difficult to see why this wear occurs.

"In the first place, one important factor is the driving or propelling action of the automobile wheels. With horse-drawn vehicles, of course, there is no driving action by the wheels, and they exert only a downward pressure or lateral pressure on the road. The rear tires of an automobile, however, exert not only a downward pressure upon the road surface, but a powerful tangential push to the rear. The average power

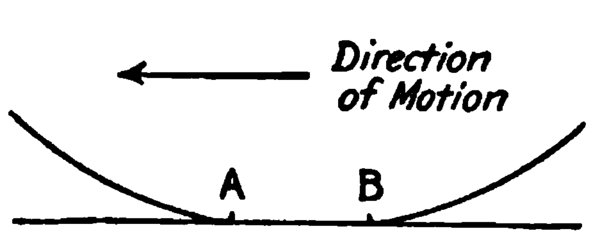

FIG. 4.

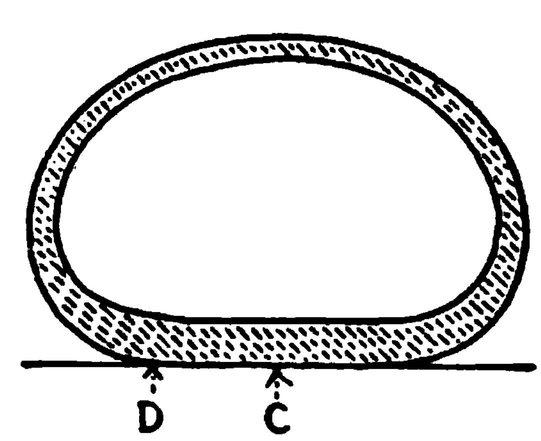

FIG. 5.

of the automobiles in common use to-day is probably from 15 to 40 H.P., and the speeds, outside of city streets, will average not less than 15 to 30 miles per hour. If we consider the elements of a rubber wheel-rim in contact with the surface of the ground, Fig. 4, it may be easily seen that the point A, which has just come into contact with the road surface, exerts no tangential action upon the road. As the wheel moves for-

ward from A to B, however, this tangential push of the surface of the rubber tire against the road rapidly increases from zero at A to a maximum at B, and as the tire lifts from the road at B and the pressure is released, the tendency is to push backward the material of the road just beneath it.

"There is another reason why the automobile tire rapidly digs a rut for itself on any road where automobiles follow each other and keep nearly in the same track. The vehicle fitted with iron tires has a flat tread; the rubber tire, either pneumatic or solid, has a tread which is more or less rounded. Suppose, in a given automobile wheel, Fig. 5, the diameter at the center of the tread at C is 30 ins.; then the diameter toward the sides of the tread at D may be ¼-in. or ½-in. less, depending upon the pressure to which the tire is pumped, the contour of the tire cross-section, the weight carried by the automobile, etc. If we take only ¼-in. difference in diameter at the points C and D, we have a difference in circumference between the central part of the tread and the sides of the tread of about ¾-in. That means that at every revolution of the wheel, either the center of the tread must slip ¾-in. forward, or the sides of the tread must slip ¾-in. backward; that is to say, there must be, theoretically and actually, this difference in the relative movement of the center and the sides of the tread upon the roadway. Actually, of course, this slip is going on all the time in the movement of a rounded tire. There is some point between the center and the side where no slip occurs, and toward the center or toward the side there is all the time a slight slip forward or backward. As a result of this action, the round-tired vehicle has more rolling friction than a vehicle with flat tires. Of course, on an ordinary roadway such as a brick pavement or a smooth macadam, the pneumatic tire, notwithstanding its rounded surface, may move with little friction because the small stones and similar obstructions which would be crushed by the iron tire will simply indent the pneumatic tire. On an ordinary dirt road, however, the rounded rubber tire has more resistance to traction than a flat iron tire.

"It is probable that the wear of the rubber tire on the roadway is more rapid as a rut begins to form and the width of contact of the tire with the road is thus increased. In the rut the sides of the tread—points where the tire diameter is an inch or even two inches less than at the center—may be in contact with the road. If the center of the tire moves in the rut without slip, the sides of the tire where the diameter is 2 ins. less must slip 6 ins. forward against the sides of the rut at every revolution. Thus the retarding action of the sides of the rut tends to increase the tangential force of the center of the tire upon the roadway and to dig the rut deeper.

"We are aware that the tearing out of the macadam surface by the pneumatic tires of an automobile has been frequently ascribed to the 'suction' of the tire upon the roadway. We do not see, however, in view of the foregoing explanation, that any 'suction' hypothesis is needed

to explain the disintegration of a macadam road surface by automobiles. Of course there is a wind current—an upward and forward suction—produced at the rear of the tires of a fast running automobile, and this wind current raises the fine dust loosened by the tire from the surface and sends it high in the air. Observation of this easily seen phenomenon has given rise to the common idea that the suction of the wheel on the road surface is what loosens the stone. Some such suction there doubtless is and it may possibly be a slight contributing cause of destruction; but any force exerted in this way must be very small compared with the terrific backward push of the rubber tire treads.

"In the light of the above discussion it is evident that little can be hoped for in the way of help for the roads through changes in automobile construction. Flat steel tires in place of pneumatic tires might possibly reduce the wear upon the roads; but the success of the automobile is dependent on noiseless and easy-riding rubber tires. Further, we are only at the threshold of our troubles with highways due to automobile wear. For two years automobile factories have been working overtime, and it is said that 200,000 automobiles are to be built next year. The burden on taxpayers to build and maintain roads to carry automobile traffic promises to become so great that a road repair tax may have to be laid on the vehicles themselves."

APPENDIX IV

STATISTICS OF PUBLIC ROADS OF THE UNITED STATES*

In the year 1904 there were 2,151,570 miles of public roads in the United States. This does not include roads in Indian Territory, Alaska, and the island possessions, as Indian Territory and Alaska were not organized, by counties in 1904, and it was impossible to secure complete information from Porto Rico, Hawaii, the Philippines and Guam. Neither does this total mileage of roads include streets or boulevards in incorporated cities and villages. Of this mileage 108,232.9 miles were surfaced with gravel, 38,621.7 miles with stone, and 6,809.7 miles with special materials, such as shells, sand-clay, oil, and brick, making in all 153,664.3 miles of improved road, or 7.14 per cent of all the roads in this country.

A comparison of the total road mileage with the area of all the states and territories, shows that there was 0.73 of a mile of road per square mile of territory, and a similar comparison with population shows that there was one mile of road to every 35 inhabitants, and one mile of improved road to every 492 inhabitants.

The majority of all the roads in this country were originally laid out along the boundary lines of farms, with little regard for drainage, topography and alignment. In the eastern states the boundary lines of farms were very irregular, and consequently many of the roads are crooked and badly located with reference to grades. In the middle west, where the land was laid out by the Government, the roads follow the section lines, and in thickly settled communities the quarter-section lines. In compiling these figures the aim was to include only the mileage of roads actually open and in use; but in reports from some of the counties in the middle west may have included a greater or less mileage of section lines, which have been set apart by law as public roads, but which have not been opened up or used for this purpose.

Only four states have more than 100,000 miles of roads. Texas stands first, with 121,409 miles; Missouri second, with 108,133; Iowa third, with 102,448; and Kansas fourth, with 101,196. The District of Columbia has only 191 miles of roads, Rhode Island has 2,361 miles, which is

* Abstracted and condensed from "Public Road Mileage, Revenues and Expenditures in the United States, in 1904"—Public Document, Bulletin No. 32, U. S. Dept. of Agriculture, in which the road statistics for all the States and Territories are given.

the smallest mileage of any state. Delaware has only 3,000, and Arizona only 5,987 miles.

By comparing the road mileage with the areas in square miles, the District of Columbia is found to stand first, with 3.18 miles of road per square mile of area, while Connecticut is highest among the states with 2.90 miles. Rhode Island has 2.24 miles, and Pennsylvania 2.21 miles per square mile of area. Arizona has only 0.05 of a mile, the smallest mileage per square mile; Utah has 0.08 and Wyoming 0.10 of a mile per square mile.

A comparison of the mileage of roads with population shows that the District of Columbia, which embraces a land area of 60 square miles and which includes the city of Washington, has the largest population per mile of public road, i.e., 1.459. Rhode Island has the largest population per mile of any state, i.e., 181 inhabitants; Massachusetts has 164, New Jersey 127, and Connecticut, 64. On the other hand, Nevada has only 3 persons per mile of public road; North Dakota has 5 persons; South Dakota has 7; Wyoming 8; Idaho and Oklahoma, 9 each; and Montana, 10.

Assuming the average width of the rights of way of country roads in the United States to be 40 feet, the area of such rights of way in 1904 amounted to 10,431,727 acres. Estimating the value of this land on a basis of the valuation of farm lands in each state, the approximate value of the rights of way of all the public roads would be $341,899,306. A much higher valuation would be amply justified by the fact that in sections where the mileage of roads is greatest the land is considerably above the average ln value. A much higher estimated value would also result from assuming that the rights of way of roads are as valuable as the contiguous farm lands, which are always worth considerably more than the general average. The value of the rights of way, however, constitutes a very small part of the value of the roads when we take into consideration the amount that is expended in material and labor in improving and maintaining them. The approximate value of rights of way is therefore given merely as an item of some importance in any calculations which may be made as to value.

It was generally believed at the time when railroad building was first undertaken in this country that the railroad would supplant the wagon road, and this line of reasoning account in a large measure for the neglect of the common roads from about 1835 until about 1890. It is now clearly demonstrated that in spite of the fact that the United States leads the world in railroad building, having a total of 213,904 miles in 1904, the necessity for the improvement of our common roads is impressing itself upon the people more now than at any time in the history of the country. Our mileage of public roads is greater now than it has ever been, and the extension of railroad and trolley lines has induced such an amazing development of the country's resources as to bring about a remarkable increase in traffic over the common roads. The heads of

the great railroad systems are now seriously directing their efforts toward securing the improvement of the common roads, which they recognize as feeders to their railroad lines. In this connection it is interesting to observe that for every mile of railroad we have about ten miles of wagon roads.

Mileage of Improved Roads. Of the 153,662 miles of improved roads in the United States, Indiana has the largest mileage—that is, 23,877 miles. Ohio occupies the second place, with 23,460 miles; Wisconsin is third, with 10,633 miles; Kentucky fourth, with 9,486 miles; California fifth, with 8,803 miles. Illinois, Massachusetts, and Michigan have over 7,000 miles each; Minnesota over 6,000 miles; New York over 5,000 miles; Tennessee over 4,000 miles; Connecticut, Maine, Missouri, New Jersey, Oregon, Pennsylvania, and Texas over 2,000 miles each; and Alabama, Georgia, Iowa, Maryland, New Hampshire, North Carolina, Rhode Island, South Carolina, Vermont, Virginia and Washington over 1,000 miles each.

In about two-thirds of the states gravel has been the principal surfacing material used in improving the roads. The largest mileage of gravel roads was found in Indiana, Ohio, Wisconsin, Massachusetts, Michigan, Minnesota, Illinois and California. In eight states the mileage of macadam roads exceeds that of gravel, and in a few others it is nearly equal. Kentucky has the largest mileage of road surfaced with stone—over 8,000 miles—and Ohio is second, with a little over 7,000. Other states with large mileage of this class are Indiana, New York, Pennsylvania, Texas, and New Jersey. About one-third of the improved roads of California were treated with oil; and almost all of the improved roads in South Carolina were surfaced with mixtures of sand and clay.

Percentage of Roads Improved. The district of Columbia occupies the first place in its percentage of roads improved, having 65.58 per cent improved. Massachusetts has 45.89 per cent, the highest percentage of any state. Rhode Island comes next, with 43.26 per cent; then follow Indiana, with 34.94; Ohio, with 33.78; California, with 18.87; Connecticut with 16.75; Wisconsin, with 16.72; Kentucky, with 16.60; New Jersey, with 16.32; Michigan, with 10.13; Maine and Maryland, each with a little over 9; Illinois, New Hampshire, Tennessee and Utah, each with over 8; and Minnesota, New York and Oregon, each with over 7 per cent. All of the states and territories except Oklahoma report some improved roads. Eleven of the states, however, report less than 11 per cent improved.

A comparison of the percentage of roads improved with the population per mile of road shows that in most cases the states which have the highest percentage of improved roads have the largest population per mile of road, and vice versa. While it cannot be claimed for improved roads that they invariably lead to an increase in population, good roads are certainly a powerful factor in encouraging immigration, especially in sparsely settled regions.

The percentage of improved roads in any community or state depends upon a variety of causes, the most important of which may be summed up as follows:

(1) Availability of suitable road-building material.

(2) Wealth of the state in agriculture, manufactories, transportation, etc.

(3) Requirements of traffic.

Prosperity promotes a desire for the advantages and benefits to be derived from the improvement of the roads; but whether a community is rich in agriculture or otherwise, if it has to depend on materials imported from distant places, progress in the improvement of the roads will be much slower than if local materials are abundant. To illustrate this point: Mississippi expended in money and labor about the same amount on roads in 1904 as Tennessee; yet Mississippi, which is very poor in road surfacing materials, has only .38 per cent of the roads improved, while in Tennessee, which is well supplied with such materials, 8.74 per cent of the roads are improved.

There are several other reasons why the percentage of improved roads is higher in some of the states than in others. The high percentage of improved roads in Massachusetts, Rhode Island, Connecticut, and New Jersey is due principally to the facts that suitable road-building materials abound, that these states are densely populated, and that many of the roads have been built through the aid of the states and under the direction of competent state authorities. Indiana and Ohio have an unusually high percentage of improved roads, because these states are abundantly supplied with good road-building stone and gravel and because the social and economic conditions were favorable to the making of public improvements.

A comparison of the percentage of roads improved with the acreage values of farm lands in the United States shows that the average percentage of the improved roads in all states where the land is worth less than $20 per acre is 1.9 per cent, whereas in the states showing an acreage value of more than $20, improved roads constitute an average of 9 per cent of the total mileage.

Expressed inversely, the states showing a high percentage of improved roads have on the average relatively high acreage values, while those showing a low percentage have low acreage values.

In Mississippi, for instance, the farm lands are worth on the average only $15.94 per acre, and in 1904 the percentage of improved roads was 0.38 of 1 per cent, while in Indiana we find that the farm lands are valued at $54.96 per acre, and the improved roads in 1904 constituted 35 per cent of the total mileage. In Arkansas the farms are worth $16.67 per acre, while the percentage of improved roads in 1904 was only 0.7 per cent. The corresponding figures for Ohio are: acreage value of farms, $57.43, and percentage of improved roads, 33.7 per cent.

While there are many factors, such as quality of the soil, the proximity

of farms to markets, and the relative population and wealth, which affect the value of the land, the figures given above indicate that the improvement of the roads constitute a most important factor in the enhancement of farm values. Records are on file to show that farm lands have been known to advance in value from 50 to 500 per cent on account of the improvement of the roads connecting them with market towns.

Of the 108,232.9 miles of gravel road in the United States, Indiana has 20,582 miles, and leads all other states in this class of roads; Ohio comes second, with 16,159 miles, Wisconsin has 9,899.8 miles, and Illinois 6,800 miles. The large mileage of gravel roads in these states is due in part to the fact that they are abundantly supplied with gravel suitable for road building, most of this being of glacial origin.

Of the 38,622 miles of road surfaced with stone, Kentucky leads with 8,078 miles; Ohio stands next with 7,160.5 miles; Indiana has 3,295 miles; New York and Pennsylvania have over 2,000 miles each, and Illinois, Massachusetts, New Jersey, Tennessee, and Texas have each over 1,000 miles.

One of the largest limestone belts in the United States extends through Kentucky, Ohio, and Indiana, and most of the stone roads in these states are built of this material. Furthermore, Kentucky has been building stone roads since 1829, most of them being constructed under the turnpike or toll system. This state also aided in this work for several years, and at the close of 1837 had invested $2,509,473 in turnpike roads. At that time 609 miles of first-class stone roads had either been constructed or were under construction.

In 1829 the old National or Cumberland road was completed in parts of Ohio, this being apparently the first stone road built in the state. From 1840 to the present time the building of stone roads has continued steadily. Some were built under the toll system, some under the one and two mile assessment plans, and others from bond issues.

The first macadamized road in Indiana was built in 1839. It was the first and only road built by the state, and extended from New Albany to Paoli. From 1850 to 1890 many stone roads were built in that state under the turnpike or toll system, and in 1885 the construction of free gravel and stone roads began—that is, roads on which travelers were not required to pay toll. From 1893 to the present time many miles of stone roads have been built by the various townships from funds received from bond issues.

Of the 6,807 miles of road in the United States surfaced with special materials, California has 2,541 miles surfaced with oil; South Carolina has 1,630 miles, nearly all surfaced with sand-clay mixtures; Florida and Georgia has each over 500 miles mostly surfaced with sand-clay mixtures; North Carolina has 438 miles surfaced with sand-clay; Maryland has 250 miles of roads surfaced with shells, and Ohio has 140.7 miles, most of which is surfaced with brick.

Oyster shells from Chesapeake Bay have been extensively used for a

number of years in building shell roads in Maryland and Virginia. A considerable mileage of shell roads is also reported for most of the Atlantic and Gulf Coast States. Ohio and Illinois appear to be the only states which have made progress in building roads of brick. Cuyahoga County, Ohio, stands first in mileage of brick roads.

EXPENDITURES. The total expenditures for public roads during 1904, by states, counties, townships, and districts, from property and poll taxes, bond issues, and state-aid funds, together with the valuation of the labor expended under the statute-labor law, amounted to $79,771,-417.87, not including Indian Territory, Alaska, or our island possessions.

Of this amount $53,815,387.98 was expended from property and poll taxes payable in cash, $19,818,236.30 was the value of the labor taxes, $3,530,470.93 came from bond issues, and $2,607,322.66 was expended from state-aid funds. By comparing the total expenditures in all the states and territories with the total mileage of all public roads and with the total population of the United States, it is found that the expenditures for road purposes amounted to $37.07 per mile of public road, or $1.05 per inhabitant.

As a bridge is usually considered a part of a road, and as taxes are, in most cases, levied and assessed for both at the same time, it was impracticable to separate road and bridge expenditures, except in the state of New York, and the total expenditures for roads has therefore been made to include those for bridges.

The amount which was expended on public roads in the United States in 1904 would represent the interest on $1,994,285,446.25, if computed on a basis of 4 per cent. When it is considered that the expenditure which this vast sum represents was for the construction and maintenance of 2,151,570 miles of public highways, enough roads to reach around the earth at the equator 86 times, it is somewhat surprising that the expenditure was not greater.

A comparison which is more to the point is that the National Government spent in the fiscal year 1903–4, $82,372,360.10 for deepening the waterways, which is about 1.3 times as much as was expended by all the states, counties, townships, and districts in the United States for the construction and maintenance of all the public highways.

APPENDIX V

BIBLIOGRAPHY OF ROADS, STREETS, AND PAVEMENTS

THE following list of books, government pamphlets, etc., has been compiled from various sources, the selection being made for the historical and practical value of the works. Many British parliamentary reports, American and foreign government bulletins, and books in foreign languages have been omitted, partly on account of their inaccessiblity and their comparatively limited usefulness and partly in order to bring the list within reasonable limits.

For convenient reference, the list is divided into three sections, (1) Previous to 1800; (2) 1800 to 1899; (3) 1900 to date, the latter period including practically all the works of current value, and in many cases, brief descriptive notes are added to indicate something of the scope of the book. Also short lists of the principal works on such allied subjects as Highway Bridges, Earthwork, Tunnels, and Forestry are given.

The publishers, or the author, will be pleased to give further information, to anyone desiring it, of any of these works regarding which such information is available.

SECTION I.—PREVIOUS TO 1800

1583. **Lambard, William.**—The Duties of Constables . . . Surveyours of the Highwaies, &c. Further editions: 1584, 1587, 1594, 1599, 1602, 1606, 1610.

1610. **Proctor, Thomas.**—A Profitable Worke to this Whole Kingdome concerning the Mending of all Highways, as also for Waters and Iron Workes.

1625. **Norden, John.**—An Intended Guyde, for English Travailers, Shewing in Generall how Far one Citie, and Many Shire-Tounes in England, are Distant from Other.

This book bears witness to the existence of a "Dark Age" period in the history of English roads, when milestones were unknown and unthought of, since at the foot of every page is printed the legend "Bear with Defects." The distances were calculated, with some curious results, from the rude maps then in use.

1635. —— ——.—A Direction for the English Traviller by which he shall be Inabled to Coast about all England and Wales.

Contains a reference to the existence of sign posts and is an improvement over Norden's former book, having a small circular map of England, and miniature outline drawings representing the various counties.

1641. **Layer, John.**—The Office and Duty of Constables . . . with the Office of Surveyors of the Highways.

1671. Broadsheet against New Buildings. A Proclamation Respecting Highways.

1675. **Mace, Thomas.**—Profit, Conveniency, and Pleasure to the whole Nation: Being a short Rational Discourse . . . concerning the Highways of England.

1675. **Ogilby, John.**—Britannia, or an Illustration of the Kingdom of England and Dominion of Wales, by a Geographical and Historical Description of the Principal Roads thereof.

The first road book from an accurate survey, the measurements being taken by means of a wheel, with a dial attached, for recording the number of revolutions made. This book was so excellent that it formed the basis of many editions for a century afterwards.

1682. The Infallible Guide to Travellers, giving a most exact account of the four Principal Roads of England.

1683. **J. M.**—The Traveller's Guide and the Country's Safety, Being a Declaration of the Laws of England against Highwaymen and Robbers upon the Road; what is requisite and necessary to be done by such persons as are robbed in order to the recovering their damages; against whom they are to bring their action; and the manner how it ought to be brought.

1692. **Littleton, E.**—Proposal for Maintaining and Repairing the Highways.

1694. **Mereton, George.**—A Guide to Surveyors of the Highways in their Duty.

1696. **Mather, William.**—Of Repairing and Mending the Highways.

1697. **D[aniel De] F[oe].**—An Essay upon Projects; "Of the Highways."

1712. **Bergier, Nicholas** (Translation from).—The General History of the Highways in all Parts of the World, more particularly in Great Britain. Ch. XXX: "The Fabulous and the True History of the Highways in England."

1715. **[Signed J. P.]**—Mending the Roads of England.

1718. The Laws concerning Travelling.

1719. **Gardner, L.**—A Pocket Guide to the English Traveller, being a Complete Survey and Admeasurement of the principal Roads, &c.

1720. The Office and Duty of . . . Surveyors of Highways, Bridges, and Causeways in Ireland.

1724. **[Watts, John.]**—A List of the Subscribers for Mending the Road from Reading to Caversham, with an account of how the money has been laid out.

1726. The Complete Parish Officer; containing the Authority and Proceedings of . . . Surveyors of Highways.

1734. A Short Specimen of a New Political Arithmetic containing some Considerations concerning Public Roads. By an F.R.S.

1737. **Phillips, Robt.**—A Dissertation concerning the Present State of the Highroads of England, especially of those near London.

1745. **Nelson, W.**—Office and Authority of a Justice of the Peace, shewing also the Duty of . . . Surveyors of the Highways.

1745–6. **Newball, John.**—A Concern for Trade, and the Various Consequences relating to the Encrease and Decrease and the Equal and Unequal Circulation of Trade.

1748. **Defoe, Daniel.**—A Tour through the whole Island of Great Britain.

1749. **Shapleigh, John.**—Highways: A Treatise showing the Hardships and Inconveniences of Presenting or Indicating Parishes, Towns, &c., for not Repairing the Highways.

1750. **Collier, James.**—Remarks on Road Bills in General, and on the Wisbech Road Bill in Particular.

1753. Proposals at large for the Easy and Effectual Amendment of the Roads by some further Necessary Laws and Regulations. By a Gentleman.

1756. A New and Accurate Description of the Present Great Roads and the Principal Cross Roads of England and Wales.

1756. An Appendix; or Further Reasons in Support of of the Plan or Proposals for the Amendment of the Roads by Way of Answer to Several Objections. By a Gentleman.

1763. **Bourn, Daniel.**—A Treatise upon Wheel Carriages.

1763. **Hawkins, John** (afterwards Sir).—Observations on the State of the Highways, and on the Laws for Amending and Keeping them in Repair.

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1765. **Whitworth, R.**—Some Remarks upon a Plan of a Bill Proposed to Parliament for Amending the Highways by Assessment instead of Six Days' Labour.

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1790. **Anstice, Robert.**—Remarks on the Comparative Advantages of Wheel Carriages of Different Structure and Draught.

1792. **Newton, Everard.**—The Whole Duty of Parish Officers, containing all the Laws now in force relative to . . . Surveyors of Highways.

1792. The Road from the Port of Milford to the Severn.

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1798. **Cary, John.**—Cary's New Itinerary; or an Accurate Delineation of the Great Roads throughout England and Wales, with many of the Principal Roads in Scotland, from Actual Admeasurement. The Eleventh Edition, with improvements, appeared in 1828.

First made by command of his Majesty's Postmaster-General for official purposes in connection with the mail coaches. Some of the southern cross roads were measured by a peculiar method, since the compiler engaged the services of George Wilson, a celebrated pedestrian, who claimed to estimate distances most exactly by the time occupied in walking from one place to another.

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1880. **Glen, Alexander.**—The Powers and Duties of Surveyors of Highways. Other editions 1881, 1888.

1880. **Goudy, Henry,** and **Smith, William C.**—Local Government in Scotland. Deals with the Law of Roads.

1880. **Thropp, James.**—Highways and Locomotives Act, 1878. Report on Main Roads (Lincolnshire).

1881. Situacion de las Carreteras del Estado—Madrid, Spain.

1881. **Spearman, R. H.**—The Law relative to Highways in England and North Wales.

1881. **Chambers, C. H.**—Public Health and Highways.

1882. **Harcourt, E. W.**—Maintenance of High Roads.

1882. **Higgins, E.**—Letters on Highway Legislation.

1883. **Boulnois, H. Percy.**—The Municipal and Sanitary Engineers' Handbook.

1883. **Glen, William Cunningham** and **Alexander.**—The Law relating to Highways, &c. Another edition, 1897.

1884. **Burrows, A. J.**—The Maintenance and Construction of Roads.

1884. The Highway Laws of Indiana.

1885. **Harris, S.**—The Coaching Age. Chapters on Highways.

1885. Laws of Indiana Respecting Highways, Free Roads, and Free Bridges.

1885. New Highway Law of Indiana.

1886. Proceedings of a Conference on Highway Management (at Gloucester).

1886. **Codrington, T.**—Roads and Streets. Encyl. Britt., Vol. XX.

1886. **Malo, Leon.**—On Asphalte Roadways.

1886. **Postu, Burton Willis.**—The Road and the Roadside. (New Edition, 1893.)

1886. **Garard, Louis F.**—Compilation of the Road Laws of the State of Georgia.

1887. **Law, H.,** and **Clark, D. Kinnear.**—Construction of Roads and Streets.

1887. **Thropp, J.**—Repairs of Roads.

1888. **Glen, W. C.**—Highway Surveyor's Guide. Second Edition.

1888. **Maudslay, A.**—Highways.

1888. Proposed Street Improvements in the City of Brooklyn.

1889. **Codrington, T.**—Local Government Board Report on Road Maintenance.

1889. **Jusserand, J. J.** (Translated by Lucy Toulmin Smith).—English Wayfaring Life in the Middle Ages. Part I.: English Roads, pp. 35–174.

1889. **Phillips, J. E.**—The Local Government Act, 1888, as it affects Highways.

1889. **Smith, Urban.**—Maintenance of Main Roads in the County of Hertford.

1889. **Jenks, Jeremiah W.** (1856-).—Road Legislation for the American State.

1889. **Pope, Col. Albert A.** (1843–1909).—Highway Improvement.

1890. **Herskell, Ferdinand.**—Treatise on Roads and Prohibition.

1890. **Haupt, Lewis M.** (1844-).—Country Roads; Their Relations to Other Lines of Communication and to the State.

1890. **Love, Edward G.**—Pavements and Roads; their Construction and Maintenance.

1890. **Pope, Col. Albert A.**—The Movement for Better Roads. The Relation of Good Streets to the Prosperity of a City.

1890. **Dykes, J. E.**, and **Stuart, D.**—Roads and Bridges Manual (Scotland).

1890. **Smith, Urban.**—The Country Roads of England.

1891. Streets and Highways in Foreign Countries—Reports from U. S. Consuls on Streets and Highways in their Several Districts.

1891. **Potter, Isaac B.**—The Gospel of Good Roads.

1891. **Bacon, A. P.**—California Asphalt: God's Natural Paving Material.

1891. **Fletcher, W.**—History of Steam Locomotion on Common Roads.

1891. **Sydney, William Connor.**—England and the English in the Eighteenth Century. Vol. II., Ch. XI.: Roads and Travelling.

1891. **Winstone, Benjamin.**—Minutes of the Epping and Ongar Highway Trust, 1769–1870.

1891. Streets and Highways in Foreign Countries. Reprinted Reports of the United States Consuls.

1891. Philadelphia. Committte on Better Roads. Essays on Road Making and Maintenance.

1892. Report of the Dept. of Public Works of New York City on Street Pavements, with Special Reference to Asphalt Pavements.

1892. **Whinery, Samuel** (1845-).—The Effect of Street Paving on the Value of Abutting Property.

1892. **Burke, Milo D.** (1841-).—Brick for Street Pavements.

1892. **Byrne, Austin T.** (1859-).—Treatise on Highway Construction. (New Editions, 1896, 1900.)

1892. **Codrington, T.**—Maintenance of Macadamized Roads.

1892. **Harper, C. G.**—The Brighton Road.

1892. **Spinks, W.**—Law and Practice as to Paving Private Streets.

1893. **Holmes, Joseph Austin** (1859-).—Road Materials and Road Construction in North Carolina.

1893. **Potter, Isaac B.**—County Roads: An Illustrated Primer of Road-Making.

1894. **Burke, M. D., C.E.**—Brick for Street Pavements. An Account of Tests Made with Bricks and Paving Blocks.

1894. **Wright, R. S.**, and **Hobhouse, Henry.**—An Outline of Local Government, England, and Wales. Second Edition. Deals with the Law of Roads.

1894. **Judson, William Pierson** (1849-).—City Roads and Pavements for Oswego, N. Y.

1894. **Spalding, Frederick P.** (1857–).—Text-book on Roads and Pavements.
1894. **Herschel, C., and North, E. P.**—The Science of Road-making . . . Construction and Maintenance of Roads.
1894. **Stone, Roy.** New Roads and Road Laws in the United States.
1894. —— ——.—Earth Roads: Hints on their Construction and Repair. (Government Bulletin.)
1894. —— ——.—State Laws Relating to the Management of Roads, enacted in 1888–93. (Government Bulletin.)
1894. Information Regarding Roads and Road-making Materials in Certain Eastern and Southern States. (Government Bulletin.)
1894. Information Regarding Roads and Road Materials in Certain States North of the Ohio River. (Government Bulletin.)
1894. Information Regarding Road Materials in Certain States West of the Mississippi River. (Government Bulletin.)
1894. **Sheffield, O. H.**—Improvement of the Road System of Georgia. (Government Bulletin.)
1894. **Brauner, John Caspar.**—Report on Road-making Materials of Arkansas. (Government Bulletin.)
1894. Ordinances Concerning the Improvement of Streets, Alleys, Sidewalks, etc., of Louisville, Ky.
1895. **Shaler, Nathaniel S.** (1841–1906).—The Geology of the Road-building Stones of Massachusetts.
1895. Report of the Joint Committee to Examine into the Condition of the Roads and Public Highways of Rhode Island.
1895. **Stone, Roy.**—Best Roads for Farms and Farming Districts; Coöperative Road Construction.
1895. —— ——.—State Laws Relating to the Management of Roads; Enacted in 1894–95. (Government Bulletin.)
1895. —— ——.—Historical and Technical Papers on Road Building in the United States. (Government Builletin.)
1895. —— ——.—Good Roads; Extracts from Messages of Governors. (Government Bulletin.)
1895. —— ——.—Wide Tires. Laws of Certain States Relating to their Use. (Government Bulletin.)
1895. **Crump, M. H.**—Kentucky Highways. History of the Old and New Systems. (Government Bulletin.)
1895. **Perkins, George Arthur.**—State Highways of Massachusetts.
1895. **Holmes, Joseph A.**—Improvement of Public Highways of North Carolina.
1895. **Shaler, Nathaniel S.** (1841–1906).—Preliminary Report on the Geology of the Common Roads of the United States.
1895. **Wheeler, Herbert A.** (1859–).—Vitrified Brick Paving.
1895. **Wallace, W. W., Jr.**—Brick Pavements.
1895. **Willmann, Leo von** (1848–).—Strassenbau.—Leipzig.
1895. **Boulnois, H. P.**—The Construction of Carriageways and Footways.

1895. **Harper, C. G.**—The Dover Road.

1895. —— ——.—The Portsmouth Road.

1896. **Hunter, (Sir) Robert.**—Preservation of Open Spaces and Footpaths and other Rights of Way.

1896. **Petsche, Albert.**—Le Bois et ses Applications au Parage.—Paris.

1896. **Lefebvre, Georges** (1860–).—Voie Publique.—Paris.

1896. **Shaler, Nathaniel S.**—American Highways; a Popular Account of their Condition.

1896. **Rockwell, Alfred P.** (1834–).—Roads and Pavements in France.

1896. **Neely, Samuel T.**—Traction Tests. (Government Bulletin.)

1897. **Merrill, Frederick J. H.** (1861–).—Road Materials and Road Building in New York.

1897. **Pratt, J. T.**, and **MacKenzie, Wm.**—Pratt's Law of Highways. Fourteenth Edition.

1897. **Whittle, C. L.**—The Forces which Operate to Destroy Roads, with Notes on Road Stones and Problems therewith connected. (Government Bulletin.)

1897. Highway Maintenance and Repairs. Taxation; Comparative Results of Labor and Money Systems; Contract System of Maintaining Roads. (Government Bulletin.)

1898. Laws of the State of Illinois in Relation to Roads and Bridges.

1898. The Highway Law of New York State.

1899. **Sioussat, St. George L.**—Highway Legislation in Maryland.

1899. **Cartland, John Henry.**—Ancient Pavings of Pemaquid, Me.

1899. **Eldridge, Maurice Owen.**—Good Roads for Farmers.

1899. —— —— ——.—Construction of Good Country Roads.

1899. **Dodge, Martin.**—Steel Track Wagon Roads.

1899. Report on the Highways of Maryland (Geographical Survey).

1899. Laws of Maryland Relating to Highways.

1899. **Conder, J. B. R.**—Handbook of Highway Cases.

1899. **Harper, C. G.**—The Bath Road.

1899. —— ——.—The Exeter Road.

1899. **Maxwell, W. H.**—The Construction of Roads and Streets.

1899. **Holmes, J. A.** (1859–).—Some Recent Road Legislation in North Carolina. (Government Bulletin.)

1899. **Maxwell, William H.**—The Construction of Roads and Streets. With Historical Sketch of the Development of the Art of Roadmaking. London. Cloth, $4\frac{1}{4} \times 6\frac{3}{4}$ ins.; 256 pages; illustrated. Price, $1.30.

A résumé of the English practice in road-building and street construction with notes on the character of materials, calculation of quantities and the various methods of systems now in use.

While the work is avowedly a compilation from many sources, it is useful as a compilation of British methods of road construction and maintenance of that time.

n. d. **Cook, John.**—Cursory Remarks on Wheeled Carriages.

n. d **Dawson, G. F. Crosby.**—Street Pavements.

n. d. **Edgworth, J.**—New Mode of Constructing Streets.
n. d. **Gilbert, Davies, M.P., F.R.S.**—A Treatise on Wheels and Springs for Carriages.
n. d. **Parry, A. W.**—The Use of Steam Rollers.

SECTION III.—1900 TO DATE

The publications in this section comprise all the works of current interest and many government documents. Each edition is listed separately and brief descriptions, with prices, are given of several standard works which can be recommended for further study.

1900. **Allen, A. T.**—Footpaths: Their Maintenance, Construction, and Cost.
1900. **Harper, C. G.**—The Great North Road. Two vols.
1900. Laws Relating to Roads, Ferries and Bridges of Mississippi.
1900. **Eldridge, Maurice Owen.**—Progress of Road Building in the United States.
1900. **Elliott, Byron K.**, and **Elliott, William F.**—Treatise on the Law of Roads and Streets.
1900. Road Laws of the State of Iowa.
1900. **Aitken, Thomas.**—Road Making and Maintenance. (Third Edition).
1900. **Tillson, George William** (1852-).—Street Pavements and Paving Materials.
1900. **Johnson, Sarah Alice.**—Facts, Suppositions, and Theories, or Road Mending, &c.
1900. **Wheeler, W. H.**—The Repair and Maintenance of Roads.
1901. **Clemens, Gasper C.**—Manual of the Laws of Roads and Highways in the State of Kansas.
1901. Road Laws of Oregon.
1901. Laws of the State of Missouri Relating to Roads, Highways, and Bridges.
1901. Recent Road Legislation in North Carolina.
1901. **Abbott, James Whitin.**—Mountain Roads. (Government Bulletin.)
1901. **Pope, Logan Waller.**—The Selection of Materials for Macadam Roads (Government Document).
1901. **McCallie, Samuel W.** (1856-).—Report on the Roads and Road-building Materials of Georgia.
1901. Le Strade di Milano—Milan, Italy.
1901. **County Councils Association.**—A Digest of Answers to a Series of Questions with Regard to the Management of Main Roads and Highways.
1901. **Greenwell, Allen**, and **Elsden, James Vincent.**—Roads: Their Construction and Maintenance, with Special Reference to Road Materials.
1901. **Harper, C. G.**—The Norwich Road.

1902. Laws of Iowa Relating to Roads, Bridges and Ferries.
1902. **Holmes, Joseph A.**—Roadbuilding with Convict Labor in the Southern States. (Government Bulletin.)
1902. **Dodge, Martin.**—Government Coöperation in Object-lesson Road Work. (Government Bulletin.)
1902. Progress of Road Legislation and Road Improvement in the Different States.
1902. **Abbott, James Whitin.**—Mountain Roads as a Source of Revenue. (Government Bulletin.)
1902. **Weicht, A. H.**—Bau von Strassen und Strassenbahnen.—Berlin.
1902. **Judson, William Pierson** (1849–).—City Roads and Pavements suited to Cities of Moderate Size. (Second Edition.)
1902. **Spalding, Frederick P.** (1857–).—Text-book on Roads and Pavements. (Second Edition.)
1902. —— ——.—The Cambridge, Ely, and King's Lynn Road.
1902. —— ——.—The Holyhead Road.
1903. Connecticut Law for the Improvement of Public Roads.
1903. Laws of the State of Missouri Relating to Roads, Highways and Bridges.
1903. **Fox, William F.** (1840–).—Tree Planting on Streets and Highways.
1903. **Laissle, Friedrich.**—Der Strassenbau Einschliesslich der Strassenbahnen.—Leipzig.
1903. **Abbott, James Whitin.**—Use of Mineral Oil in Road Improvement.
1903. **Page, Logan Waller.**—The Testing of Road Materials. (Government Bulletin.)
1903. **Buckley, Ernest Robertson** (1872–).—Highway Construction in Wisconsin.
1903. **Baker, Ira Osborn** (1853–).—Treatise on Roads and Pavements. (First Edition.)
1903. **Codrington, T.**—Roman Roads in Britain.
1903. **Gilbey, Sir Walter, Bart.**—Early Carriages and Roads.
1903. **Jeffreys, W. Rees.**—Highway Administration in England and Wales at the Beginning of the Twentieth Century.
1903. **Latham, F.**—Construction of Roads, Paths, and Sea Defences. With Portions relating to Private Street Repairs, Specification Clauses, Prices for Estimating, and Engineer's Replies to Queries.
1903. **Stephens, J. E. R.**—Digest of Highway Cases, with all the chief Statutes on Highways, Bridges, and Locomotives.
1903. **Tillson, George W.**—Street Pavements and Paving Materials. A Manual of City Pavements; the Methods and Materials of Their Construction. For the Use of Students, Engineers and City Officials. New York. Cloth, 6×9 ins.; xii+532 pages; 60 illustrations. Price, $4.00.

Contents: History and Development of Pavements; Stone; Asphalt; Brick-Clays and the Manufacture of Paving Brick; Cement, Cement Mortar and Concrete; Theory of Pavements; Cobble and Stone-Block Pavements;

Asphalt Pavements; Brick Pavements; Wood Pavements; Broken-Stone Pavements; Plans and Specifications: Construction of Street-Car Tracks in Paved Streets; Width of Streets and Roadways, Curbs, Sidewalks, etc.; Asphalt Plants.

1903. **Latham, Frank.**—The Construction of Roads, Paths, and Sea Defences. With Portions relating to Private Street Repairs, Specification Clauses, Prices for Estimating, and Engineers' Replies to Queries. London. Cloth, 6×9 ins. Price, $3.00, net.

This book discusses the necessity of good roads for traction, line of roadway, setting out, drainage and coverings of roads, road-rolling, stone-breaking, paving with wood, stone, brick, artificial slabs, etc. Short chapters also deal with scavenging, watering, and snow removal from roads. A portion of the book is devoted to sea-walls, with illustrations of walls at Penzance and Margate (England), and also short chapters on road bridges and artificial stone plants. Useful specification clauses on roads and streets, sewers, and sea-walls, and also a table of approximate prices of road materials, are added at the end of the book, and in a pocket in the cover is a tabulated statement of details of road construction, compiled from replies of various engineers and of interest for reference.

1904. The New State Aid Road Law (Maryland).

1904. **Maxwell, William H.**—British Progress in Municipal Engineering.

1904. **Beery, P. B.**—Portland Cement Sidewalk Construction.

1904. **Page, Logan Waller.**—The Cementing Power of Road Materials. (Government Bulletin.)

1904. **Craig, A.**—The Railroads and the Wagon Roads. (Government Bulletin.)

1904. **Drummond, R., C.E., F.S.A.** (Scot.).—The Evolution of Road Making in Scotland. Paper Read before the Scottish Automobile Club.

1904. **Fairless, Michael.**—Roadmender. Re-issue.

1904. **Ferguson, James.**—The Law relating to Roads, Streets, and Rights of Way in Scotland.

1904. **Forbes, N. A.**, and **Burmester, A. C.**—Our Roman Highways.

1904. **Hasluck, Paul N.**—Road and Footpath Construction.

The British and Irish Road Book.—Issued by the Cyclists' Touring Club.

Vol. I.—Southern and South-Western Counties. Sixth Edition.
Vol. II.—Eastern and Midland Counties, including Wales. Second Edition. 1898.
Vol. III.—Northern Counties. Third Edition. 1899.
Vol. IV.—Scotland. Second Edition. 1901.
Vol. V.—Southern Ireland. 1899.
Vol. VI.—Northern Ireland. 1900.

The most complete description of British roads available at the present time, through which, and similar volumes contained in this list, the gradual growth of the roads can be traced over a period of nearly three centuries.

1904. **Spoon, William Luther.**—Building Sand-clay Roads in Southern States. (Government Bulletin.)

1904. **Richardson, Robert W.**—Progress of Roadbuilding in the Middle West. (Government Bulletin.)

1904. Asphalt Paving.—Report of Commissioners of New York City.

1905. **Harper, C. G.**—The Oxford, Gloucester, and Milford Haven Road.

1905. **Richardson, Clifford** (1856–).—The Modern Asphalt Pavement.

1905. **Wallace, Henry** (1836–).—How to Make Good Dirt Roads.

1905. **Lancaster, Sam C.**—Practical Road-building in Madison Co., Tennessee. (Government Bulletin.)

1905. **Cushman, Allerton S.**—A Study of Rock Decomposition under the Action of Water. (Government Bulletin.)

1905. Manual for Iowa Highway Officers.

1905. **Hurlbert, Archer Butler** (1873–).—The Future of Road-making in America.

1905. Connecticut Law for the Improvement of Public Roads.

1905. Statutes of the State of Oregon Relating to Roads, etc.

1905. Road Laws of the State of Idaho.

1905. Improvement, Repair, and Maintenance of Public Highways of the State of New York.

The publication of this book of instructions and suggestions was made advisable by the numerous changes in the highway laws of the State of New York. It sets forth a uniform system of town accounting of highway funds and also contains a compilation of statistics of the cost and maintenance of highways and bridges throughout the state.

1905. **Allen, A. Taylor.**—New Streets: Laying Out and Making Up. London. Cloth, 6×9 ins.; 175 pages. Price, $1.20, net.

The purpose of this book is chiefly to serve as a condensed form of reference and examples of carrying out the essential parts and work entailed by the British "Surveyor under the Public Health Act" of 1875, and the "Private Street Works Act" of 1892. It deals strictly with British practice.

1906. Proceedings of the Good Roads Conference held at Denver, Colo., 1906.

1906. Pennsylvania Road Laws.

1906. Report of Royal Commission on Motor Cars.—London.

1906. **Guinn, James Miller** (1834–).—El Camino Real. An Investigation into the History of early Roads in California.

1906. **Lovegrove, E. J.**—Attrition Tests of Road-making Stones. With Petrological Description by John S. Flett, M.A., D.Sc., and J. Allen Howe, B.Sc. London. Cloth, 8½+11½ ins.; xix+80 pages; 79 illustrations. Price, $2.00.

These studies relate chiefly to specific rocks in Great Britain, but they contain considerable information of general interest. After a few paragraphs outlining the character of his investigations, the author submits tables giving attrition tests from a large number of quarries and a considerable variety of stones. The petrological descriptions are classified by granite, porphyry, basalt, and other groups, and are accompanied by photomicrographs. The descriptions are also supplemented by general conclusions.

1906. **Baker, Ira O.** (1853–).—Drainage of Earth Roads.

1906. Tar and Oil for Road Improvement. (Government Bulletin.)

1906. **Spoon, William Luther.**—Construction of Sand-clay and Burnt-clay Roads. (Government Bulletin.)

1906. **Hotchkiss, William Otis.**—Rural Highways of Wisconsin.

1906. **Gillette, Halbert Powers** (1869–).—Economics of Road Construction. Second Edition; Enlarged. Cloth, 6×9 ins.; 49 pages; 9 illustrations. Price, $1.00, net.

This small book gives a great deal of useful information in clear, brief, and concise language. The contents are: Historical Review; Earth Roads and Earthwork (Profile of Cross-section of Road, Longitudinal Profile, Gutters and Drains, Embankments, Cost of Earthwork, Surfacing, Traction and Tractive Power, Location); Gravel Roads; Macadam Roads (What Holds Macadam Together, Quality of Stone, Relative Wearing Powers of Stone, Quarrying, Dynamite, Crushing, Hauling, Spreading, Rolling, Sprinkling, Quantity, and Cost); Telford Roads; Repairs and Maintenance (Continuous vs. Intermittent System, Sandstone Macadam); Suggested Improvements in Existing Road Specifications (Kind and Sizes of Broken Stone, Depth of Pavement, Final Surfacing, Material for Embankments, Thickness and Width of Pavements); Summary and Conclusions.

1906. Laws Relating to Highways and Bridges of Michigan. (Supplement, 1907).

1906. **Allen, A. Taylor.**—Footpaths: Their Maintenance, Construction and Cost.

1906. **Baker, Ira O.**—The Construction and Care of Brick Pavements.

Reprint of part of a report on "The Paving Brick Industry of Illinois," prepared for the Illinois State Geological Survey.

1907. **Lord, Edwin C. E.**—Examination and Classification of Rocks for Road Building, Including the Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (Government Bulletin.)

This pamphlet is decidedly technical in character, but for engineers and others who wish to go thoroughly into the science of macadam-road building materials it contains information of much value.

1907. **Page, Logan W.**—Object-lesson Roads. (Government Bulletin.)

1907. **Whinery, Samuel** (1845–).—Specifications for Street Roadway Pavements. New York. Paper, 6×9 ins.; 56 pages. Price, 50 cents, net.

"The large and successful experience of the author in the construction of pavements, and his studious habits and carefulness of language, make any article he may write upon the subject of especial interest.

"The author's conclusions respecting guarantees, taken in connection with the form of the guarantee of work and material, should meet with general approval both by municipalities and contractors. . . . The pamphlet is a valuable contribution to the literature upon the proper construction of pavements."—*Engineering News*, Aug. 15, 1907.

The specifications cover General Work, Foundations, Bituminous Pavements, Granite, Brick and Wood Block Pavements.

1907. Road Laws of New Castle County, Delaware.

1907. Connecticut Law for the Improvement of Public Roads.

1907. **Byrne, Austin Thomas** (1859–).—A Treatise on Highway Construction. Designed as a Text-book and Work of Reference for all who may be engaged in the Location, Construction and Maintenance of Roads, Streets and Pavements. Fifth Edition, Revised and Enlarged. New York. Cloth, 5¾×9¼ ins.; xliii+1,024 pages; 309 illustrations; 92 tables. Price, $5.00.

In the preface to the first edition of this work, published in 1892, the author states:

"Although volumes have been written on the subject of highway construction, still, the matter is widely scattered through the pages of

the standard works on engineering, technical journals, and periodicals, in pamphlets and reports of city engineers, and is, therefore, not always easily accessible when wanted. The author, having found the need of a comprehensive and practical work of reference upon the many subjects connected with highways, has in the following pages endeavored to collate the varied mass of information."

In order to keep abreast of the times, further editions of the book were issued in 1896 and 1900, and in the present one, an extensive revision was made, bringing the work thoroughly up to date.

The book treats of every branch of the subject and may be said to be cyclopedic in character. The titles of the chapters are: Pavements, Materials employed in the Construction of Pavements, Stone Pavements, Wood Pavements, Asphaltum and Coal-Tar Pavements, Brick Pavements, Broken-Stone Pavements, Miscellaneous Pavements, Foundations, Resistance to Traction, Location of Country Roads, Width and Transverse Contour, Earthwork, Drainage and Culverts, Bridges, Retaining Walls, Protection Works, Tunnels, Fencing, City Streets, Foothpaths, Curbs, Gutters, Reconstruction and Improvement of Country Roads, Maintenance-Repairing, Cleansing, Watering, Trees, Staking Out the Work, Specifications and Contracts, Implements and Prices, Miscellaneous Notes. Four Appendices: Naming and Numbering Country Roads and Houses; Methods of Assessing the Cost of Street Paving; Ordinance Regulating the Width of Wagon-tires; Cycle Paths.

The treatment of the various chapters is quite full and satisfactory. There are over three hundred illustrations and there is a remarkably comprehensive index, covering 93 pages.

1907. **Hirst, Arthur R.**—Road Pamphlets. Wisconsin, Geological and Natural History Survey. No. 1: Earth Roads. No. 2: The Earth Road Drag. No. 3: Stone and Gravel Roads. No. 4: Culverts and Bridges.

These are popular expositions on the subjects indicated, and should be useful for their intended purpose of aiding in the good road movement.

1907. **Buckley, Ernest Robertson** (1872-).—Public Roads; Their Improvement and Maintenance.

1907. **Eldridge, Maurice Owen.**—Public-road Mileage Revenues and Expenditures in the United States in 1904. (Government Bulletin.)

Gives statistics by states and counties showing the character and extent of public roads, the expenditures therefor and the way in which the money is raised, also contains a synopsis of the road laws of various states and a tabular comparison by states of the percentage of improved roads, the value of farm lands, and the value of rights of way.

1907. **Fletcher, Austin B.**—The Construction of Macadam Roads. (Government Bulletin.)

Gives a good idea of methods employed in constructing macadam roads, especially as carried out under the direction of the Massachusetts Highway Commission. The materials and appliances used are described; drainage, preparation of the subgrade and the placing of the macadam are discussed. Extracts from specifications used in various states are given, also cost data, and drawings of culverts.

1907. Annual Report of the Commissioner of Highways for the Year 1908. (Maine.)

Reviews the work of the year and gives some interesting cost data. A reprint of the proceedings of the First New England Road Conference, held in Boston, Nov. 23-24, 1908, is given.

1907. **Patton, W. M.**—A Treatise on Civil Engineering. New York. Second Edition. Cloth, 6×9 ins.; 1,672 pages; 464 illustrations and diagrams. Price, $7.50.

In this voluminous treatise, nearly all branches of engineering science that could be grouped under the general title of "Civil Engineering," have

been treated. Location of Highways and Country Roads has been covered in one chapter, followed by a chapter on Location of Lines of Communication by Topographical Maps and one on Resistance to Traction on Highways.

1907. **Goodhue, W. F.**—Municipal Improvements. A Manual of the Methods, Utility and Cost of Public Improvements for the Municipal Officer. Third Edition. Cloth, 4×6 in.; viii+207 pages; illustrated. Price, $1.50.

This book is intended not for the technical reader, but for the members of the town council and for the non-professional reader. There are 30 chapters, of which two treat of street surface and street grades and one of highway bridges.

1908. **Leighton, Henry.**—Road Materials of Southern and Eastern Maine.

1908. **Hubbard, Prevost.**—Dust Preventives. (Government Bulletin.)

This circular is rather a summary and compilation of principles than a record of experimental work.

1908. **Page, Logan W.**—Dust Preventives. (Government Bulletin.)

1908. Progress Reports of Experiments with Dust Preventives. (Government Bulletin.)

1908. **Hill, Cary LeRoy.**—Wood Paving in the United States. (Government Bulletin.)

This pamphlet takes up the progress of wood paving, the qualities of creosoted wood pavement, problems in wood paving, laying the pavement, maintenance and a descriptive discussion of an experimental pavement.

1908. **Palliser, Charles.**—Modern Cement Sidewalk Construction. A Practical Treatise for the Workman. New York. Cloth, 5×7 ins.; pp. 64; illustrated. Price, $0.50.

The construction of cement sidewalks, curbs and gutters is concisely explained in this book, directions being given regarding the selection and testing of the cement, sand, stone, gravel, etc., the special tools used; the laying, finishing, seasoning, coloring, etc.; together with cost data for a number of cases, with complete specifications for each. Simple language has been used throughout the book, and all technical terms introduced are clearly defined.

1908. **Ryves, Reginald Arthur.**—The King's Highway. The Nature, Purpose and Development of Roads and Road Systems. London and New York. Cloth, 8½×11½ ins.; 96 pages; 34 illustrations. Price, $2.00, net.

This book is largely devoted to English roads and in many ways it is quite different from other road books. There are 21 comparatively short chapters dealing with Foreign (outside of Great Britain) Road Systems, Some Points of Foreign Practice, Road Administration in the United Kingdom, The Departmental Committee of 1903, Highway Law, Mechanical Power Traction, Width and Safety, The Road Crust—Wearing and Weathering Roads, Road Lamps and Carriage Lamps, Special Roads, Maintenance and Repair, Road Stones, Tests of Road Stones, Wheels, Dust and Prevention—Tar-Macadam, Bridges, Climate, and Geology, The Roadside, Frost, Wind and Snow.

1908. **Richardson, Clifford** (1856–).—The Modern Asphalt Pavement. Second Edition, Revised and Enlarged. New York. Cloth, 5½×9½ ins.; 629 pages; 42 illustrations. Price, $3.00.

"The object of this book is to demonstrate the nature of asphalt pavements and the causes of defects in them, to bring about improvement in the methods of their construction, and to show how this can be done.

"The conclusions which are advanced are the results of twenty years' experience in the industry by the writer with pavements in

over one hundred cities in the United States and several in England, Scotland, and France, involving the construction of between twenty and thirty million yards of surface."—EXTRACT FROM INTRODUCTION.

The contents are divided into nine parts: The Foundation and Intermediate Course; The Materials Constituting the Asphalt Surface Mixture; Native Bitumens in Use in the Paving Industry; Technology of the Paving Industry; Handling of Binder and Surface Mixture on the Street; The Physical Properties of Asphalt Surfaces; Specifications for, and Merits of Asphalt Pavements; Causes of the Defects in, and the Deterioration of Asphalt Surfaces; Control of Work; Appendix.

This is one of the recognized standard books on the subject of road work—in a lengthy review of the first edition (1905) *Engineering News* speaks in most favorable terms of it and says: "It is not too much to say that Mr. Richardson's book should be classed with those which appear too infrequently, but whose appearance mark epochs in the industry to which they relate."

1908. **Spalding, Frederick Putnam** (1857–).—A Text-book on Roads and Pavements. Third Edition, Revised and Enlarged. New York. Cloth, 4¾×7½ ins. 340 pages; 51 illustrations. Price, $2.00.

"The aim of this work is to give a brief discussion, from an engineering standpoint, of the principles involved in highway work, and to outline the more important systems of construction with a view to forming a text which may serve as a basis for a systematic study of the subject."—EXTRACT FROM PREFACE.

"While it is primarily intended as a text-book for classes in engineering schools, it will be found a convenient and satisfactory handbook for non-professional and general readers who wish to inform themselves in the elementary principles of designing and constructing roads and pavements. . . . The arrangement of subjects and chapters does not differ materially from the other leading books on roads and pavements, . . . but within the appropriate scope of a college text-book, the author has accomplished all that could reasonably be demanded."—*Engineering News*, Dec. 17, 1908.

Contents: Road Economics and Management; Drainage of Streets and Roads; Location of County Roads; Improvement and Maintenance of Country Roads; Broken Stone Roads; Foundation for Pavements; Brick Pavements; Bituminous Pavements; Wood-Block Pavements; Stone-Block Pavements; City Streets.

1908. **Morrison, Charles Edward.**—Highway Engineering. New York. Cloth, 5¾×9 ins.; 315 pages; 60 illustrations. Price, $2.50.

The preface states that this book was prepared as a text-book for second-year students in the Civil Engineering department of Columbia University, with a view to furnishing a text in which the fundamentals of the subject should not be buried in a mass of detail; and further states that the book is not a reference work, but rather one in which it has been the endeavor to outline and emphasize those basic principles which are essential to good highways. The contents cover: Road Resistances, Earth Roads, Gravel Roads, Broken-stone Roads, Miscellaneous Roads, Street Design, Stone Pavements, Brick Pavements, Asphalt Pavements, Modern Wooden Pavements.

1908. **Brandt, Charles Edward** (1847–).—Road Locating and Building Simplified. For Use in the Common Schools. Boards, 5×7¾ ins.; 106 pages; illustrated. Price, $1.00.

This book was written for use in the common schools and is of little practical value to the engineer. It contains the rudiments of road making and endeavors to simplify the art of road location and construction to the level of elementary studies with the hope of educating the school pupils up to the good-roads idea.

1908. **Byrne, Austin T.**, and **Phillips, Alfred E.**—Highway Construction. A Practical Guide to Modern Methods of Roadbuilding and the Development of Better Ways of Communication. Cloth, 6½×9¾ ins.; 136 pages; 79 illustrations and 2 plates. Price, $1.00.

This is an elementary book consisting mainly of a brief epitome of Byrne's cyclopedic volume, "A Treatise on Highway Construction."

1908. **Boorman, Thomas Hugh** (1851-).—Asphalts: Their Sources and Utilizations. New York. Cloth, $6\frac{1}{4} \times 9\frac{1}{4}$ ins.; 216 pages; 48 full-page plates. Price, $3.00.

A comprehensive manual in the asphalt industry. The first eleven chapters are devoted to descriptions of the occurrence, properties, and uses of the various forms of asphaltic substances. Two chapters then follow on the developments of the asphalt industry. Asphaltic oils and their application to roads for the purpose of making them dustless are discussed in the succeeding six chapters. There are then included chapters dealing with municipal asphalt plants, asphalt waterproofing, asphalt for manufacture, and a short chapter on asphalt machinery.

1908. Supplement to Pennsylvania Road Laws.

1908. **Coane, John M., Henry, E., and John M., Jr.**—Australasian Roads. A Treatise, Practical and Scientific, in the Location, Design, Construction and Maintenance of Roads and Pavements. Melbourne, Australia. Cloth, $5\frac{1}{2} \times 8\frac{3}{4}$ ins.; 334 pages; 13 illustrations.

The title of this book is somewhat misleading. Instead of being a treatise on the method of road building in Australia, as one might expect from the title, it is a compilation of data on the best practice in road engineering in other countries for the guidance of Australasians.

1908. **Judson, William Pierson** (1849-).—Road Preservation and Dust Prevention. New York. Cloth, $5\frac{3}{4} \times 8\frac{1}{4}$ ins.; 146 pages; illustrated. Price, $1.50, net.

Mr. Judson has rendered the road engineers and the road makers of the country a valuable service in collecting and sifting the great mass of data on the subject of dust prevention scattered through periodicals and society transactions and in reducing this material to a condition that permits of comparisons being made, giving officials who are not experts reliable information to guide them in the selection of a suitable remedy for the cure of their own local troubles.

The opening chapter treats of the origin of road dust and its economic value in the preservation of the road surface. The other eight chapters deal with the various means of treatment and construction with a view toward dust prevention, taking up, respectively, Moisture, Oil Emulsions, Oils, Coal-tar Preparations, Tar-spraying Machines, Tar-macadam, Rock-Asphalt, Macadam and Bitulithic Pavement. Each chapter describes the general process, its variations and details of experiments, giving methods of use, results, costs, and a summary of conclusions arrived at based on a consideration of the details of many experiments. The comparative values of the various methods and their suitability for local conditions as brought out, will enable road builders to profit by the experience of others and thus save much of the cost of experimenting for themselves.

1908. **The Control of Street Openings.** A Discussion Concerning an Ultimate Remedy for the Destruction of City Pavements by Openings.

1908. **Baker, Ira O.**—A Treatise on Roads and Pavements. New York. New Printing of 1903 Edition. Cloth, 6×9 ins.; 655 pages; 65 tables; 171 illustrations. Price, $5.00.

Consists of two parts: I.—Country Roads, including matters relating to earth, gravel and broken-stone roads in rural districts; II.—Street Pavements. The reason for this division is given in the introduction:

"The problems involved in the construction and maintenance of rural highways differ materially from those which are encountered in the improvement and care of city streets . . . In each division of the subject certain general principles will first be considered, and the further discussion will be divided according to the several materials in use for the road surface. . . .

In a review in *Engineering News* (February 19, 1903) the merits and limitations of this book were compared in detail with those of the various other works on the subject, and the conclusions reached were summarized in one paragraph:

"Having considered the whole treatise somewhat in detail, we may say that as a text-book for students this new work is superior to Byrne, but partly because it is more recent. It is also superior to Tillson, but chiefly because it is more comprehensive. Tillson wrote with a much wider experience than has any other author of a manual on pavements, but he held himself closely to that subject, even to the exclusion of sidewalks. This limitation is commendatory, but must be borne in mind when assigning Tillson a place among other treatises on road and street work. But when we look at Baker's work from the viewpoint of the engineer already possessed of most of the American works above mentioned, we find very little that is not to be found in them and in recent current literature. The author has compiled with excellent judgment, but excepting some original data on traction, voids in sand and stone, and analyses of certain gravels, we find no real contribution to the stock of engineering knowledge of roads and pavements."

1908. **King, David W.**—The Use of the Split-log Drag on Earth Roads. (Government Bulletin.)

1908. **McCullough, Ernest.**—Engineering Work in Towns and Small Cities. Second Edition. Chicago. Cloth, $4\frac{3}{4}\times7\frac{3}{4}$ ins.; 510 pages; illustrations and tables. Price, $3.00, net.

In the introductory chapter the author writes:

"This book is written for two classes of officials in towns and cities having a population of less than 20,000 inhabitants, and it may be found useful in some larger places.

"Elected officials and those who have no technical education belong to the first class. They come into intimate relations with men who have charge of engineering work, are interested in it, oftentimes direct it, and therefore may be benefited by reading this book.

"The second class is composed of engineers and surveyors holding the position of town or city engineer, especially those with little or no previous experience in municipal engineering."

Three chapters (100 pages) are devoted to Roads and Streets; Walks, Curbs, and Gutters; Street Pavements.

1908. **Aitkin, Thomas.**—Roadmaking and Maintenance. A Practical Treatise for Engineers, Surveyors and Others. With an Historical Sketch of Ancient and Modern Practice. Second Edition. London. Cloth, $6\times9\frac{1}{4}$ ins.; 525 pages; 167 illustrations. Price, 21*s*.; American, $6.00, net.

This is a British book, but its recognized usefulness has made it a standard work in America as well as in England. The results of a wide experience are set down in a clear and orderly fashion, supplemented by well-chosen illustrations.

The contents are divided into two parts: (1) Macadamized Roads and (2) Carriageways and Footpaths. The titles of the chapters are: Part I. —Road-Making and Maintenance—Historical Sketch; Resistance to Traction—Wheels and Weights on Them; Laying Out New Roads and the Improvement of Existing Lines of Communication; Earthwork, Drainage, Retaining Walls, Culverts, Bridges and Protection of Roads; Road-Making Materials; Quarrying; Stone-Breaking and Haulage; Road-Rolling and Scarifying; The Construction of New and the Maintenance of Existing Roads; The Prevention of Dust. Part II.—Carriageways and Footways—Preliminary Remarks—Foundations and Pitched Pavements; Wood Pavements; Asphalt Pavements; Brick Pavements for Carriageways; Tar Macadam; Conclusions; Footways-Paving Materials for Footpaths, Curbs, Channels, Gutters; Testing the Surfaces of Carriageways; Subways.

The first edition of Mr. Aitkin's book was brought out in 1900 and was very favorably received. It appeared at a time when the art of road-making had not advanced to as high a state of perfection in this country as in Great Britain, and it was particularly useful as recognizing the value and describing the methods of substituting machine for hand labor in both construction and maintenance. It also gave detailed figures of cost and, while these are, of course, of far less use in this country than in England, owing to the variation in local conditions and in currency systems, the fact that many of these were inserted to show the relative advantages of different methods, make them of some interest to American engineers. The present edition has been thoroughly revised. The greater part of the

volume relates to the construtcion of macadam and like roads, but the various kinds of city pavements are also considered.

In an Appendix of 50 pages is given the full text of a report on "The Resistance of Road Vehicles to Traction," made to the British Association for the Advancement of Science, by a committee of which the author was a member.

1909. Judson, William Pierson (1849–).—City Roads and Pavements. Suited to Cities of Moderate Size. Fourth Edition, Revised. New York. Cloth, $5\frac{3}{4}\times8\frac{3}{4}$ ins.; 197 pages; 69 illustrations. Price, $2.00, net.

This book deals especially with the many varieties of hard-surfaced roads, and has for a number of years been considered a standard guide to the building of rural highway and town streets, as well as of city pavements.

Some interesting historical matter in early stone wheel tracks in America are given; also tables for determining standard crowns, giving the cost of asphalt pavements, grades and costs of different kinds of pavements and other valuable information of like character.

The titles of the chapters are: Preparation of Streets for Pavements; Ancient Pavements; Modern Pavements; Concrete Base for Pavement; Stone-Block Pavements; Concrete Pavements; Wood Pavements; Iron-Slag Block Pavements; Vitrified-Brick Pavements; American Sheet-Asphalt, Artificial and Natural; Bitulithic Pavement; Broken Stone Roads.

1909. Smith, J. Walker.—Dustless Roads. Tar Macadam. A Practical Treatise for Engineers, Surveyors and others. London. Cloth, 6×9 ins.; 225 pages; 24 illustrations. Price, $3.50, net.

This book is based largely upon a long continued intimate personal experience in dealing with the subject of tar macadam.

Over thirty pages are devoted to the production and refinement of tar. The standardization of the matrix and associated tests, the aggregate, the different methods of preparing and laying tar macadam (four chapters), and mechanical mixing are then taken up and later in the book the effects of wear, porosity, density, and distribution of weight, scavenging or road cleansing, watering, and maintenance generally; camber or crown, grade, noiselessness, and hygienic advantages and wearing and tractive effort are considered.

The final chapter, entitled "Tar Spraying or Spreading Ordinary Macadam Surfaces," contains considerable information on tar spraying, as well as interesting but brief history of the practice. An appendix gives in tabulated form replies received to inquiries regarding "tar macadam and the tarring of macadam surfaces," made by various British municipal engineers. These returns are also drawn upon by the author from time to time throughout a large part of his text, thus supplementing his own experience and ideas with those of others.

1909. Vinsonneau, Jules.—Le Route Moderne.—Paris.

1909. Harris, G. Montagu.—The First International Road Congress, Paris, 1908. London. Cloth, 6×9 ins.; 140 pages; Price, $1.50.

1909. Thomson, Sanford E.—Concrete in Highway Construction. $1.00.

1910. Frost, Harwood.—The Art of Roadmaking. New York. Cloth, 6×9 ins.; 544 pages; 260 illustrations. Price, $3.00, net.

An explanation of the problems involved in the building of roads, the various roadmaking materials, qualities of roads suited for various purposes, and other information written in a style suitable for the general reader.

EARTHWORK AND ROCK EXCAVATION

Allen, C. F.—Tables for Earthwork Computation. $1.50.

Baker, B.—Lateral Pressure Earthwork. $0.50.

Crandall, C. L.—Railway and Other Earthwork Tables. Third Edition. $1.50.

Crockett, C. W.—Methods for Earthwork Computations. $1.50.

Cunningham, D. W.—Earthwork Tables. $4.25.

Gillette, H. P.—Rock Excavation, Methods and Cost. 1904. $3.00.

1903. Gillette, H. P.—Earthwork and Its Cost. New York. Cloth, 5×8 ins.; 244 pages; tables, folding plates and illustrations. Price, $2.00, net.

There are 17 chapters treating of: The Art of Cost Estimating; Earth Shrinkage; Earth Classification and Cost Data for all kinds of work in connection with excavating, grading, dredging, digging, filling, etc.

1905. Gillette, H. P.—Handbook of Cost Data for Contractors and Engineers. A Reference Book giving Methods of Construction and Actual Costs of Materials and Labor on Numerous Engineering Works. Chicago. Morocco, 4½×6¾ ins.; 610 pages; 30 illustrations and many tables. Price, $4.00, net. (See page 533.)

As explained by the title, this book is a record of costs of actual work. It deals with many classes of engineering practice, one section (Sec. II.) being devoted to "Cost of Earth Excavation"; one (Sec. III.) to "Cost of Rock Excavation, Quarrying, and Crushing," and one (Sec. IV.) to "Cost of Roads, Pavements, Walks," etc. Macadam and telford roads, the various kinds of pavements, curbs, gutters, and walks are discussed and their detail costs set forth. The first two sections are principally a synopsis and condensation of the author's books; "Earthwork and Its Cost" and "Rock Excavation—Methods and Cost," both of which are elsewhere noticed.

1907. Henderson, R. S.—Earthwork Tables. New York. Heavy paper; oblong; 32 pages. Price, $1.00, net.

Divided into two parts:
Part I.—Preliminary Earthwork Tables, giving cubic yards per 100 feet for level sections, to which is added a graphical method of estimating quantities from a profile.
Part II.—Earthwork Tables, giving the volume in cubic yards of prismoids 100 feet long by the average and area method.
This is a very useful book of tables; exceptionally complete, wide in range and compact in arrangement.

Grace's Earthwork Tables for Calculating the Cubical Contents of Cuttings. 1908. $5.00.

Housden, C. E.—Practical Earthwork Tables. 1907. $0.90.

Howard, C. R.—Earthwork Mensuration. $1.50.

Hudson, J. R.—Tables for Calculating Cubic Contents of Excavations, etc. $1.00.

Morris, E.—Easy Rules for Measurement of Earthwork. $1.50.

Prelini, C.—Earth and Rock Excavation. 1904. $3.00.

Taylor, T. U.—Prismoidal Formulæ and Earthwork. $1.50.

Trautwine, J. C.—Method of Calculating Cubic Contents of Excavations and Embankments by Diagrams. Ninth Edition. $2.00.

Warner, J.—New Theorems, Tables, and Diagrams for Computation of Earthwork. $4.00.

BLASTING AND EXPLOSIVES

Andre, G. G.—Rock Blasting. $3.00.

Berthelot, M.—Explosives and Their Power. $9.60.

Daw, A. W., and Z. W.—Principles of Rock Blasting. Part I. $6.00.

Eissler, M.—Hand-book on Modern Explosives. $5.00.
—— ——.—Modern High Explosives. Third Edition. $4.00.
Foster, J. G.—Submarine Blasting in Boston Harbor. $3.50.
Guttman, O.—Blasting. $3.00.
Maurice, W.—Electric Blasting Apparatus and Explosives. $3.50.
Sanford, P. G.—Nitro-Explosives. $3.00.

CULVERTS AND DRAINS

Chamberlain, W. I.—Tile Drainage. $0.35.
Dempsey, G. D.—Drainage of Lands, Towns, etc. $1.80.
Jones, E. R.—Notes on Drainage. $1.00.
Klippart, J. H.—Principles and Practice of Land Drainage. $1.00.
Marston, A.—Sewers and Drains. $1.00.
Miles, M.—Land Draining. $1.00.
Scott, J.—Draining and Embankment. $0.60.
Waring, G. E.—Drainage for Profit and Health. $1.00.

HIGHWAY BRIDGES

Boller, A. P.—Construction of Iron Highway Bridges. $2.00.
1721. **Gautier, Hubert** (1660–1737).—Traité de la Construction des Chemins.
1850. **Geddse, George.**—Observations on Plank Roads.
1899. Report on the Highways of Maryland.
1901. **Cooper, T.**—General Specifications for Foundations and Substructures of Highway and Electric Railway Bridges. $1.00.
1901. **Law, Henry.**—The Construction of Roads and Streets. Sixth Edition.
1904. **Fowler, C. E.**—Ordinary Foundations. $3.50.
n. d. **Osborn Engineering Co.** General Specifications for Highway Bridge Superstructures. $0.25.
n. d. **Thacher, E.**—General Specifications for Highway Bridges. $0.25.
1906. **Buel, Albert W.**—General Specifications for Steel Railroad Bridges and Structures, with a section making them applicable to Highway Bridges and Buildings. $0.50.
1908. **Watson, W. J.**—General Specifications for Concrete Bridges. $1.00.
1908. **Ketchum, Milo S.**—The Design of Highway Bridges and the Calculation of Stresses in Bridge Trusses. New York and London. Cloth, 6×9 ins; xxi+554 pages; 309 illustrations; 77 tables. $4.00, net.

"The aim in writing this book has been to give a brief course in the calculation of the stresses in bridge trusses, followed by a systematic discussion of the details and design of highway bridges.

"While there are many excellent books in which the different types of railway bridges are discussed in detail, little attention has heretofore been given to the design of highway bridges. As a consequence of this neglect, many of our highway bridges have been very badly designed; the design of these structures being ordinarily left to an engineer without experience, or to the agent of some bridge company, who is more interested

in the resulting profits than in obtaining a good design. The calculation of the stresses in highway and railway bridges are similar, but the problems in the design of the two types are very different, due to the different requirements and conditions.

"In the course of the calculation of stresses, both the algebraic and the graphic methods of calculating stresses in bridge trusses are described in detail."—EXTRACT FROM PREFACE.

The above extract from the Preface will give a general idea of the nature of the book. It was primarily written for the purposes of a text-book for engineering schools, but, on the other hand, it is also intended to meet the needs of municipal and county engineers, surveyors, and all men engaged in highway bridge construction, whose duties require a knowledge of design and construction, and as the first book on the specific subject of highway bridges that has been published for some time, it is deserving of the most careful consideration.

The contents are divided into three parts: Stresses in Steel Bridges; The Design of Highway Bridges; and a Problem in Highway Bridge Details. Part I. deals with Types of Steel Bridges; Loads and Weights of Highway Bridges; Methods for the Calculation of Stresses in Framed Structures; Stresses in Beams; Stresses in Highway Bridge Trusses; Stresses in Railway Bridge Trusses; Stresses in Lateral Systems; Stresses in Pins; Eccentric and Combined Stresses; Deflection of Trusses; Stresses in Rollers and Camber; the Solution of Problems in the Calculation of Stresses in Bridge Trusses. Part II. takes up Short Span Steel Highway Bridges; High Truss Steel Highway Bridges; Plate Girder Bridges; Design of Truss Members; The Details of Highway Bridge Members; The Design of Abutments and Piers; Stresses in Solid Masonry Arches; Design of Masonry Bridges and Culverts; The Design of Timber and Combination Bridges; Erection, Estimates of Weight and Cost of Highway Bridges; General Principles of Design of Highway Bridges. Part III. discusses in detail the design of a 160-ft. Pratt truss span.

1909. **Tyrell, H. S.**—The Longest Simple-Truss Span Highway Bridge. Paper, 6×9 ins.; 22 pages, 15 diagrams, and 1 half-tone view. Price, 50 cents.

This pamphlet describes the highway bridge over the Miami River at Elizabethtown, Ohio, which is remarkable as being the longest simple-truss span in existence.

FORESTRY

Brown, J. P.—Practical Arboriculture, 1906. $2.50.
Bruncken, E.—North American Forests and Forestry. $2.00.
Fernow, B. E.—Economics of Forestry. $1.50.
Fuller, A. S.—Practical Forestry. $1.50.
Gifford, J.—Practical Forestry for Beginners. $1.20.
Hough, F. B.—Elements of Forestry. $.1.50
Hough, R. B.—American Woods. Each part, $5.00.
Houston, E. J.—Outlines of Forestry. $1.00.
Nisbet, J.—Studies in Forestry. $2.00.
Roth, F.—First Book of Forestry. $1.20.
Schwartz, G. F.—Forest Trees and Forest Scenery. $1.50.
Schlich, W.—Manual of Forestry. 5 vols. $17.20.
Springer, J. S.—Forest Life and Forest Trees. $1.50.
Typical Forest Trees. 3 ser. $1.00. Each, $0.40.
Unwin, A. H.—Future Forest Trees, 1906. $2.25.

TUNNELING

While this branch of engineering is not necessarily connected with the work of the municipal engineer and road builder, a knowledge of tunnel practice is useful.

1905. **Prelini, Charles.**—Tunneling: A Practical Treatise. New York and London. Cloth, 6×9 ins.; 326 pages; 150 illus. Price, $3.00.

The general purpose of this book is to explain all the operations that are required in tunneling and to illustrate by suitable examples the actual application of these methods in practice.

1906. **Stauffer, David McN.**—Modern Tunnel Practice. Illustrated by Examples taken from Actual Recent Work in the United States and in Foreign Countries. New York. Buckram, 6×9 ins.; 322 pages; 138 illustrations. Price, $3.50, net.

The material used in this book is taken largely from the detailed descriptions of modern tunnel work found in the pages of technical journals, personal notes and in the proceedings of engineering societies, supplemented by the experience of many engineers and contractors. In every case the description of any especial method is prefaced by a brief statement of the physical conditions which called for some particular treatment. The composition, nature, and use of modern explosives have been treated at considerable length. An important feature is a glossary of all the technical and some of the more unusual terms used in tunnel work.

1910. **Gillette, H. P.**—Handbook of Cost Data for Engineers and Contractors. Second Edition. Chicago. Morocco, 4½×6¾ ins.; 1854 pages; illustrated. Price, $5.00, net.

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